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By G. Bretz

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ADVANCED CARGO TRANSFER FACILITY - FINAL FEASIBILITY REPORT

ABSTRACT This report documents the feasibility of the Advanced Cargo Transfer Facility (ACTF). The ACTF would be used to transfer containers from commercial containerships anchored offshore to supply points ashore at an advanced base location. The ACTF is transported by commercial vessels and offloaded and assembled by Amphibious Construction Battalion personnel. Containers would be transferred at a rate sufficient to support a Marine Expeditionary Force. The facility may be employed in total or specific hardware developments may be used to upgrade current Navy systems. The technology developments fostered by the ACTF will expand the Navy's capability for transferring cargo while reducing the shipping required to transport the ACTF by two-thirds compared with current systems. Using ACTF technology, a 2,500-foot-long pier can be deployed from a single ship. The ACTF consists of a series of 16 foundation modules which are positioned and then jacked up. Folding spans stored inside the modules are then extended to provide the link to shore. Eight mooring modules and two dolphin modules berth the containership next to the pierhead. The crane ship transfers containers directly to the pier, where the container mover transfers them to shore. Since small boat operations are not required, transfer can continue into sea state 4. Anchors and foundations that can function on rock or sediment seafloors will open up previously inaccessbile areas.

NAVAL CIVIL ENGINEERING LABORATORY PORT HUENEME CALIFORNIA 93043-5003

METRIC CONVERSION FACTORS

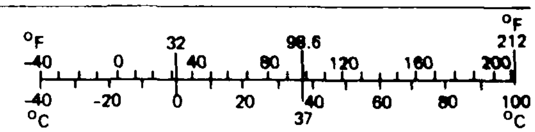
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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This report documents the feasibility of the Advanced Cargo Transfer Facility (ACTF). The ACTF would be used to transfer containers from commercial containerships anchored offshore to supply points ashore at an advanced base location. The ACTF is transported by commercial vessels and offloaded and assembled by Amphibious Construction Battalion personnel. Containers would be transferred at a rate sufficient to support a Marine Expeditionary Force. The facility may be employed in total or specific hardware developments may be used to upgrade current Navy systems. The technology developments fostered by the ACTF will expand the Navy's capability for transferring cargo while reducing the shipping required to transport the ACTF by two-thirds compared with current systems. Using ACTF technology, a 2,500-foot-long pier can be deployed from a single ship. The ACTF consists of a series of 16 foundation modules which are positioned and then jacked up. Folding spans stored inside the modules are then extended to provide the link to shore. Eight mooring modules and two dolphin modules berth the containership next to the pierhead. The crane ship transfers containers directly to the pier, where the container mover tranfers them to shore. Since small boat operations are not required, transfer can continue into sea state 4. Anchors and foundations that can function on rock or sediment seafloors will open up previously inaccessible areas.

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INTRODUCTION

This report documents the feasibility of the Advanced Cargo Transfer Facility (ACTF) (Figure 1) (Ref 1 and 2). The development of the ACTF evolved from an ambitious set of requirements. The ACTF will provide resupply of a Marine Expeditionary Force (MEF). This assault follow-on echelon resupply provides the MEF with an additional 60 days of supplies. The ACTF system will provide a method of transferring containerized cargo from containerships, anchored in 50 feet of water, to the beach. The system will perform this function using less manpower and in higher sea states than the current Container Offload and Transfer System (COTS), and the ACTF itself will be less of a logistics burden to transport.

Mission

The ACTF transfers containers from commercial containerships anchored offshore to supply points ashore at an advanced base location. The ACTF is transported by commercial vessels and offloaded and assembled by Amphibious Construction Battalion personnel. The ACTF transfers containers at a rate sufficient to support a Marine Expeditionary Force (more than 50,000 Marines and sailors). The facility may be employed in total or specific hardware developments may be used to upgrade current Navy systems.

Developmental Objective

The objective is to develop ACTF technology that will expand the Navy's capability for transferring cargo while reducing the shipping required by two-thirds compared with current systems. Using ACTF technology, a 2,500-foot-long pier can be deployed from a single ship. The ACTF consists of a series of 16 foundation modules which are positioned and then jacked up. Folding spans stored inside the modules are then extended to provide the link to shore. Eight mooring modules and two dolphin modules are used to berth the containership next to the pierhead. The crane ship transfers containers directly to the pier, where the container mover transfers them to shore. Since small boat operations are not required, transfer can continue into sea state 4. Anchors and foundations that can function on rock or sediment seafloors will open up previously inaccessible areas.

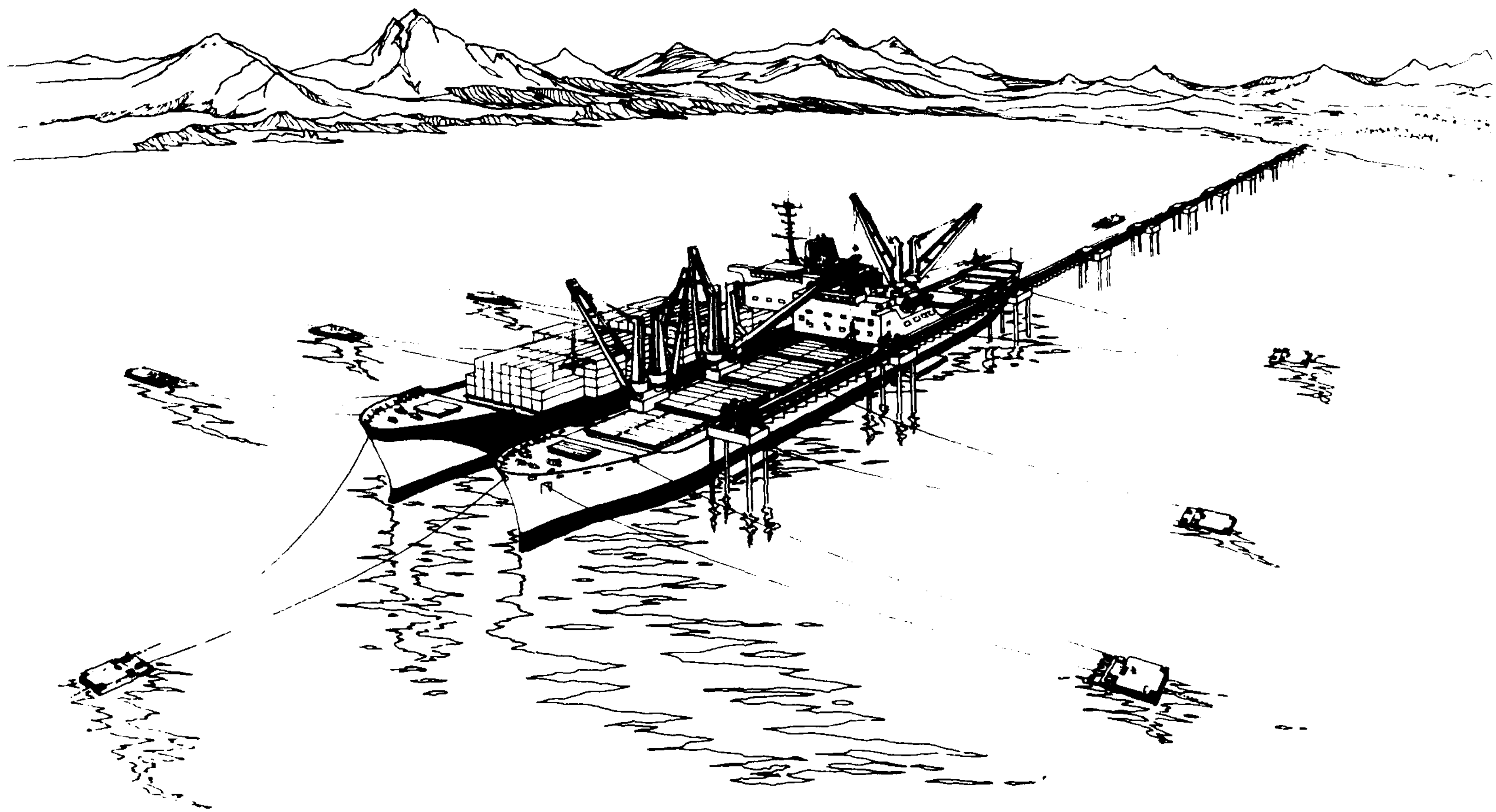

Figure 1. Advanced cargo transfer facility.

ACTF CONCEPT

Foundation

Jack-up platforms (Figure 2) will be used to support the lightweight spanning structures. These platforms use automated pile handling systems to reduce manpower required for installation and will adapt deep water jack-up techniques to the nearshore environment. The ACTF employs a universal footing incorporating a water jet array for sediment seafloors and a hardened steel spike for rock seafloors.

Spanning and Cargo Handling

A low volume expandable span coupled with a container mover (Figure 3) will replace bulky pontoon causeways and provide the bridge from ship-to-shore. The ACTF has a nominal length of 2,500 feet. This will accommodate a 1:50 seafloor slope, but the ACTF may be assembled in various lengths and configurations to accommodate variations in bottom slope. The span is a folding structure that can be produced in lengths up to 400 feet. Cargo handling components raise, lower, and move containers along the span to shore. "Container mover" systems employ linear induction motor technology to transport containers from the pierhead to the beach. A hopper will be provided to reduce the time required to place containers on the pierhead.

Mooring and Berthing

Ship mooring and berthing components restrain a containership (and TACS vessel) adjacent to the seaward end of the ACTF pier. The ship berth in 50 feet of water will accommodate one or two (nested) ships of 35,000 deadweight tons (dwt). Winch-equipped anchor barges (Figure 4) aid in berthing and mooring ships. Rapidly installable mooring dolphins (Figure 5) provide fendering for berthed ships. Propellent embedment anchors (Figure 6), which can be used on sediment or rock seafloors, will be used to secure other components.

CONSTRAINTS

Environment

The development of technology to produce an ACTF was initiated because there are shortfalls in the operational capability of current cargo offloading systems. Current systems are ineffective in sea state 3 and above because of reliance on lighterage for cargo transport. One of the ACTF objectives is to develop technologies to permit operations in conditions up to sea state 4.

Operational Requirements

Efficiency. The ACTF will be installed with a 50 percent manpower reduction when compared with current container discharge systems. This is accomplished by extensive use of pre-engineered structures and automated components.

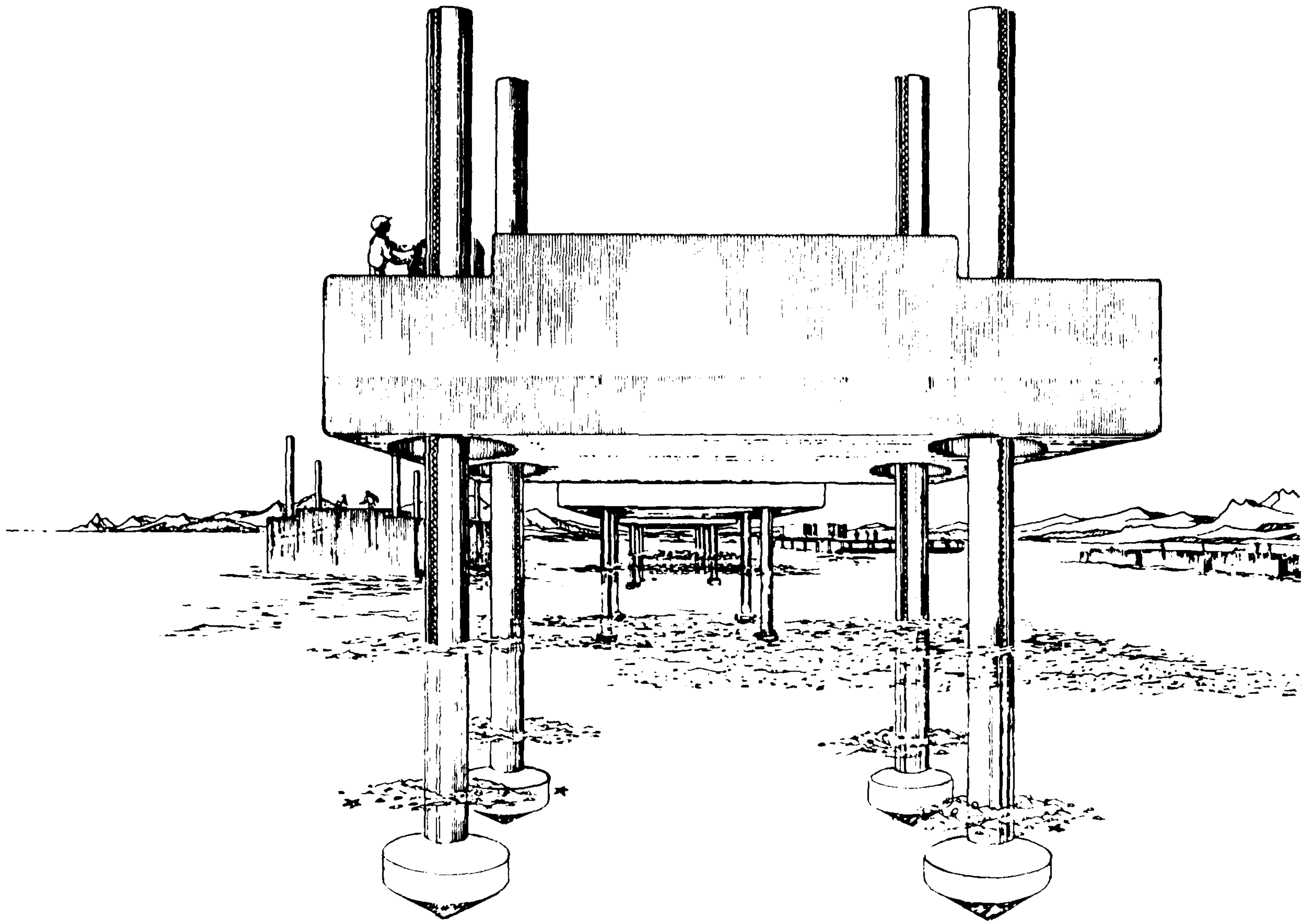

Figure 2. Jack-up platforms.

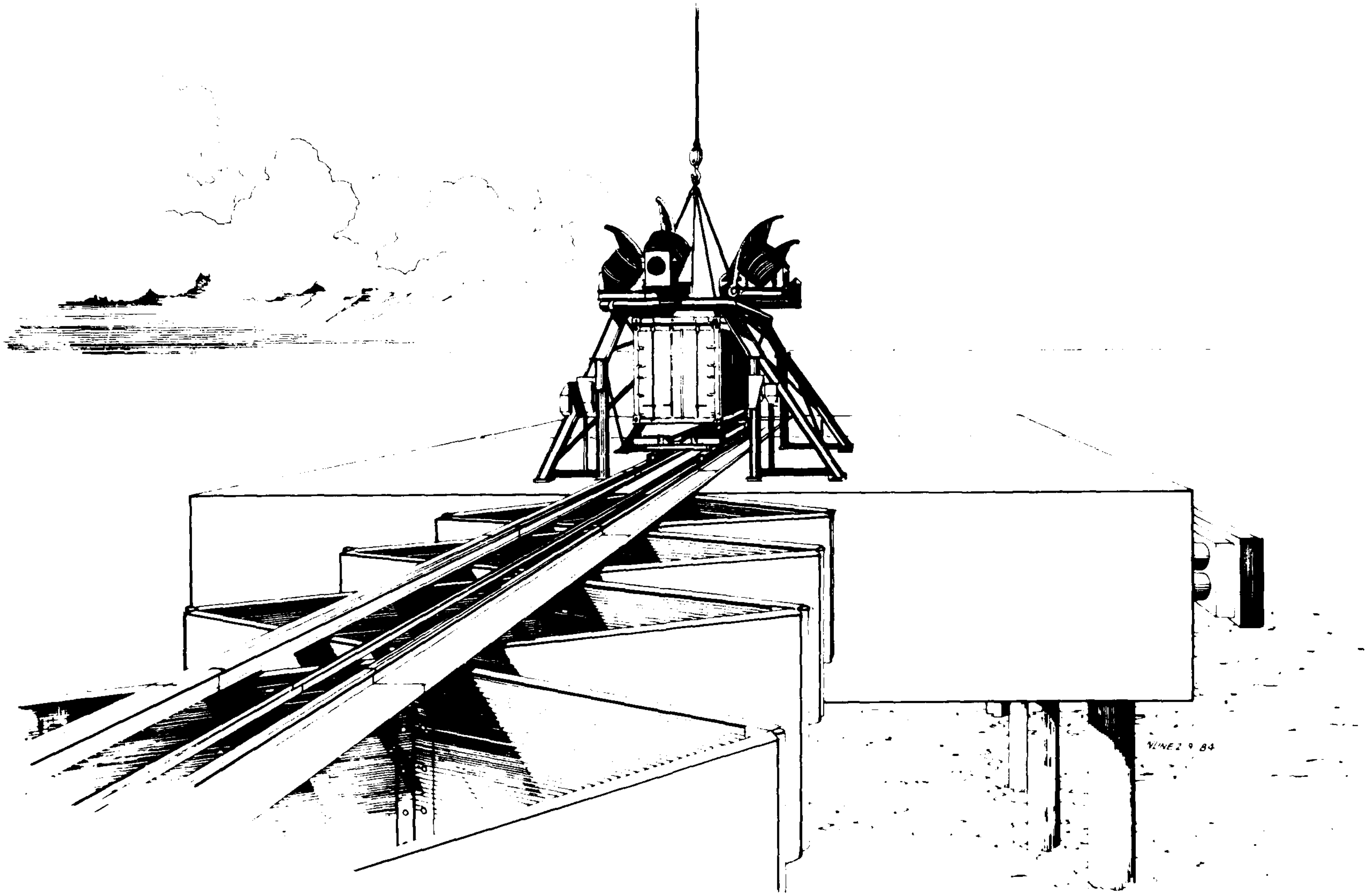

Figure 3. Span and container mover.

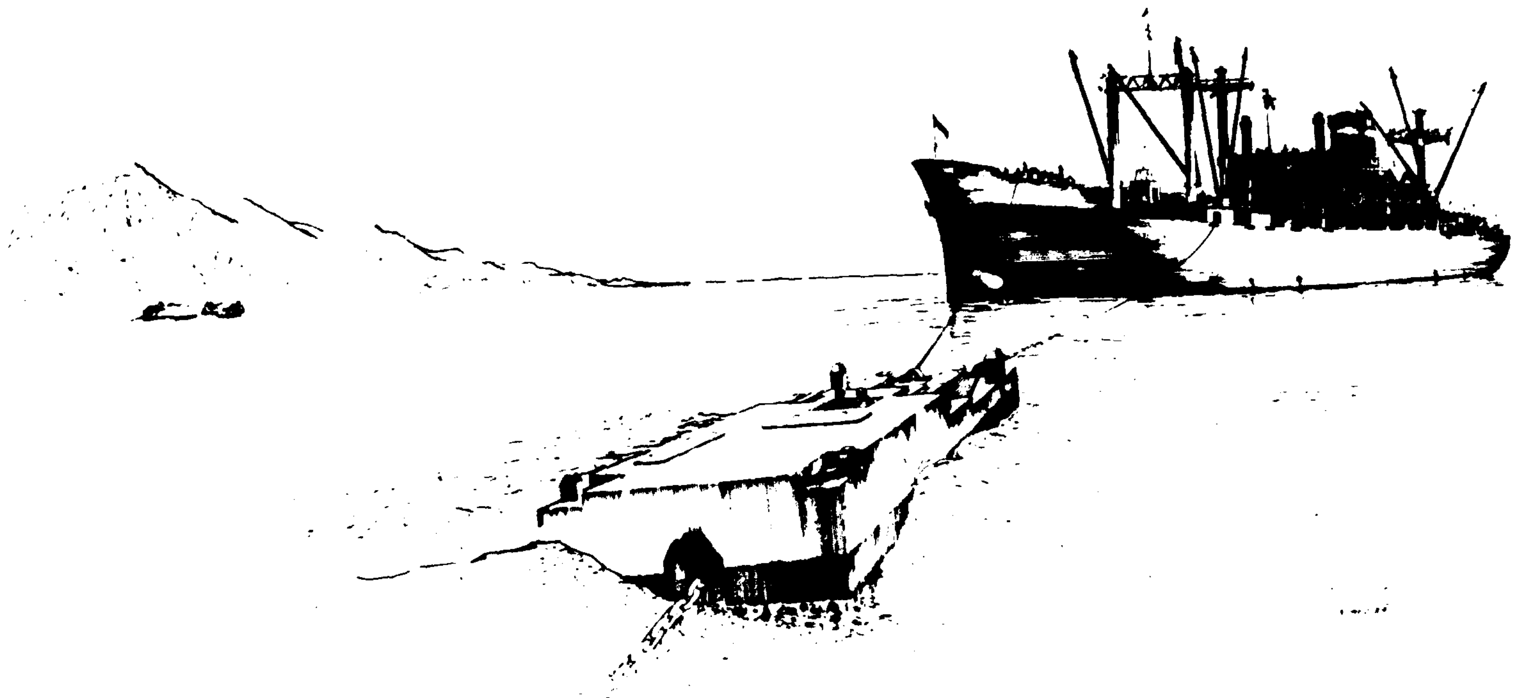

Figure 4. Anchor barges.

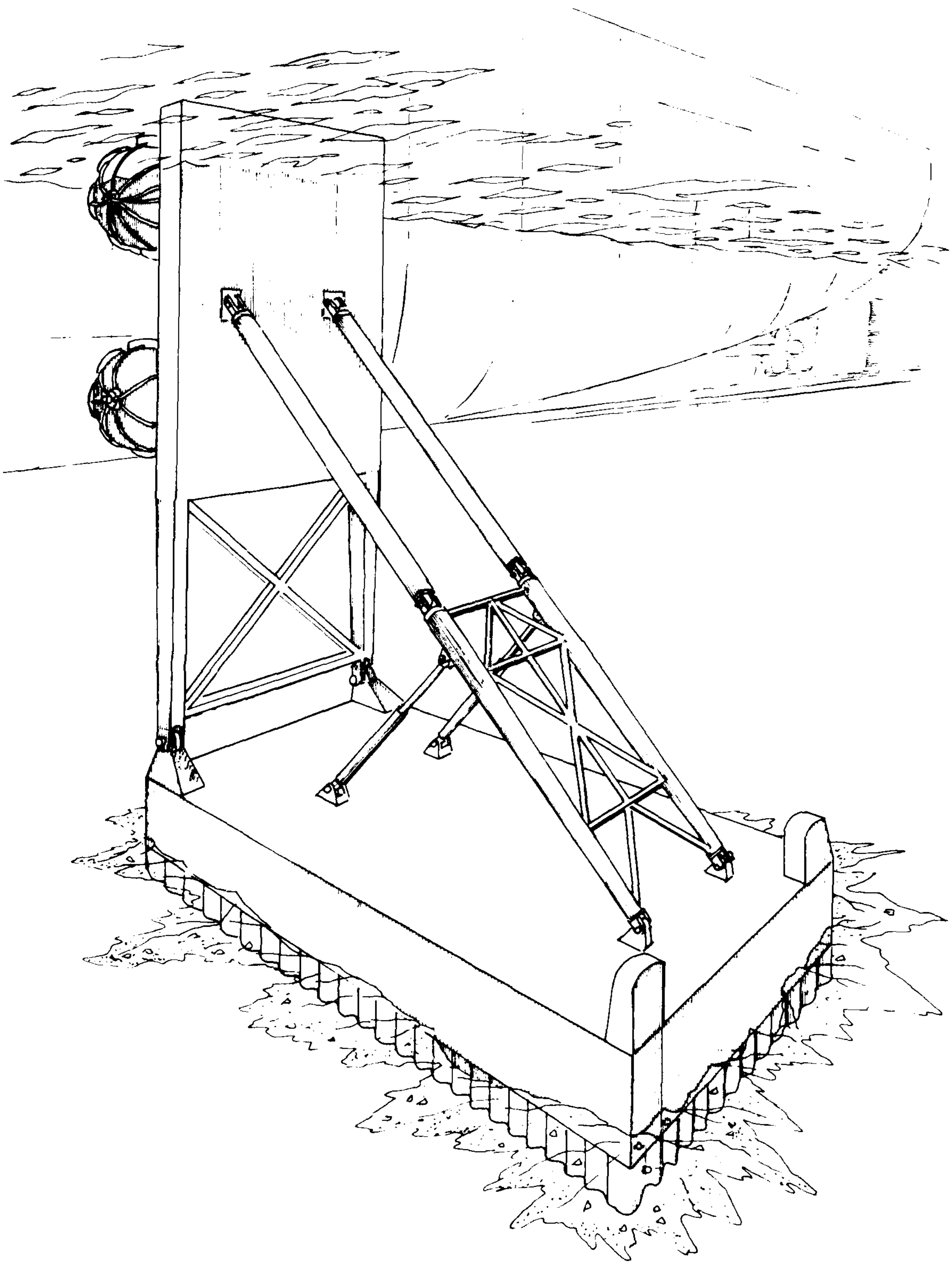

Figure 5. Mooring dolphin.

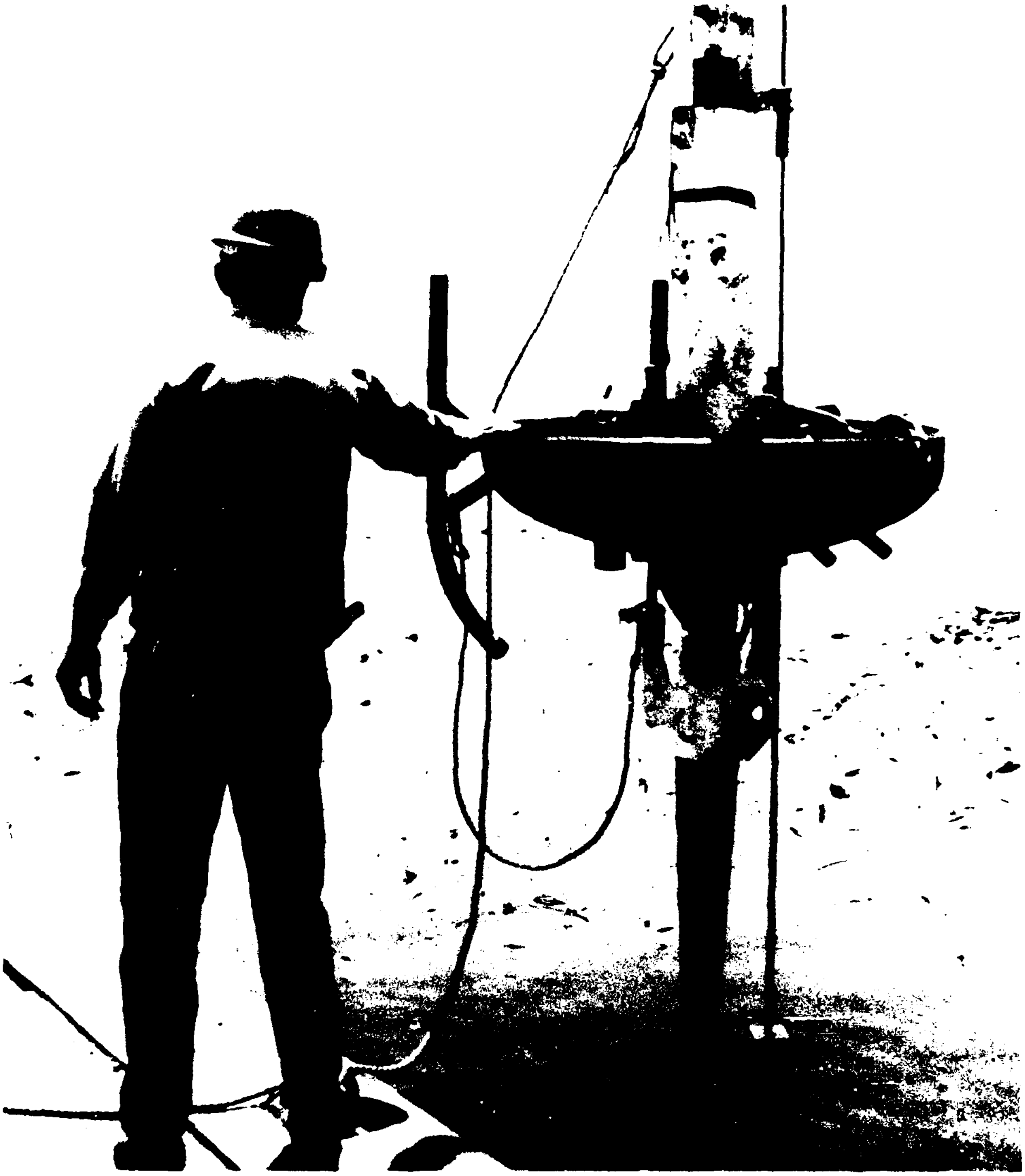

Figure 6. Propellant embedment rock anchor.

Logistics. The ACTF will reduce the shipping requirements by two-thirds when compared with other container discharge systems. The reduction of shipping cube is accomplished by designing space efficient components.

FOUNDATION TECHNOLOGIES

The jack-up foundation system provides supports for a spanning structure and a transfer system that transports containers from a containership to shore. These foundation supports can function in seafloor conditions ranging from soft mud to hard rock. The foundation technique, mobile jacking platforms, is classified as a shallow foundation and in its modular form resembles a table with legs. A spudcan is mounted at the base of each leg, which develops high bearing capacity in soft material; in rock seafloor, a spike located at the bottom of the spudcan develops bearing capacity at the rock surface.

The system will be designed to resist wind loads acting against the structure. The leg dimensions and spacing are sized to resist the lateral loading due to wind, waves, and ocean currents acting on the legs. The diameter and wall thickness of the legs have been selected to support the dead load (i.e., the jack-up module, the spanning structure, the container transporting system) and the live loads (including fully loaded containers and the environmental forces acting on the container). The foundation is not designed to resist ship mooring and berthing loads or breaking waves against the platform.

The modular jack-up foundation system is virtually automatic if properly maintained. Each foundation module stores a 480-foot complement of support leg sections (i.e., 120 feet per assembled leg). The modules fit the envelope of the spaces in the LASH ship and are LASH transportable. Each module is easily deployed from the LASH ship by the 500-ton gantry crane located on the ship, but requires a tug for maneuvering in the water. Automatic systems onboard each module, one per leg, elevate leg sections to the main deck, transfer the leg sections to an upending mechanism, upend the section to a vertical attitude, and control the section for joining to another section in the spudwell. The joining of two sections, also automated, uses a rigid split snap ring mechanism which requires only that the two sections be pushed together. The upending mechanism is designed to control the joining of each section. Each mechanism operates independently from the other three legs so that all four legs can be assembled simultaneously. Once a leg is fully assembled (i.e., a 120-foot-long support leg), the jacking mechanism controls the lowering of the leg through the water to the seafloor. Jacking continues to push the legs into the seafloor and when sufficient resistance is achieved from the seafloor soil (e.g., 20 feet of penetration required for soft material), the module begins to elevate above the water. A water jetting system operating through the spudcan provides for deeper penetration of the legs when needed. Theoretically, this operation can be accomplished by one man working at a computer controlled console board. Realistically, though, several men should be available for lubrication and repair of the mechanical systems onboard as well as rigging duties associated with positioning procedures.

Leg Handling Mechanism (Ref 3)

The ACTF is designed to be transported by a LASH ship. To accomplish this, the 120-foot-long support legs of the jack-up module had to be reduced to four 30-foot sections and stored inside the module. The compactness of the leg storage allows the foundation module to be carried in the barge holds of a LASH vessel. A leg handling mechanism for each support leg was developed to reassemble the support legs once the module is deployed at the operating site. The handling mechanism removes a leg section from storage and positions it over the spudwell for splicing onto the support leg.

Sixteen 36-inch-diameter 30-foot-long leg sections are stored in the module. As Figure 7 shows, the sections are distributed in four stacks with each stack containing four leg sections and canted to feed a particular spudwell. Leg sections are removed from storage by an elevator which feeds the section into a leg handling mechanism. This mechanism has two components: a moving cart on rails which supports a lock pin assembly, and a leg upending framework that also has a lock pin assembly and is hinged at the rim of the spudwell. The lock pin assemblies use the rack teeth attached to the leg section to secure the section while hydraulic cylinders move the section toward the spudwell via the moving cart.

From the operator's console, the lock pin on the moving cart is lowered to mesh with rack teeth while the fixed lock pin is retracted. The hydraulics are then activated to draw the section into the leg handling framework. Two such strokes can drag the section end flush with the rim of the spudwell. The leg section is then ready for upending. Both lock pins are engaged to secure the leg section. The tipping cylinders upend the assembly through a 90-degree arc until poised in a vertical position above the spudwell with the section in vertical alignment with the end of the support leg. The leg handling mechanism lowers the leg section onto the support leg. A special mechanical joint, explained next, is used to join the 30-foot section to the support leg. These procedures are repeated four times to achieve the 120-foot-long support leg.

Leg Splicing Mechanism (Ref 3)

As discussed previously, the jack-up foundation unit will be transported with the legs stowed in 30-foot sections. It is therefore necessary to quickly assemble the sections into 120-foot legs. The most common methods of joining two pile sections together are by welding or by threading. Both are time consuming, labor intensive, and require additional equipment. Welding two sections together requires that each section be butted end to end and aligned for straightness. The equipment and manpower required are a welding machine, a welder, and rigging equipment to keep the sections aligned during welding. The threading alternative is similar to making up threaded plumbing pipe. This method requires a large turntable for rotating a section and large tongs for gripping.

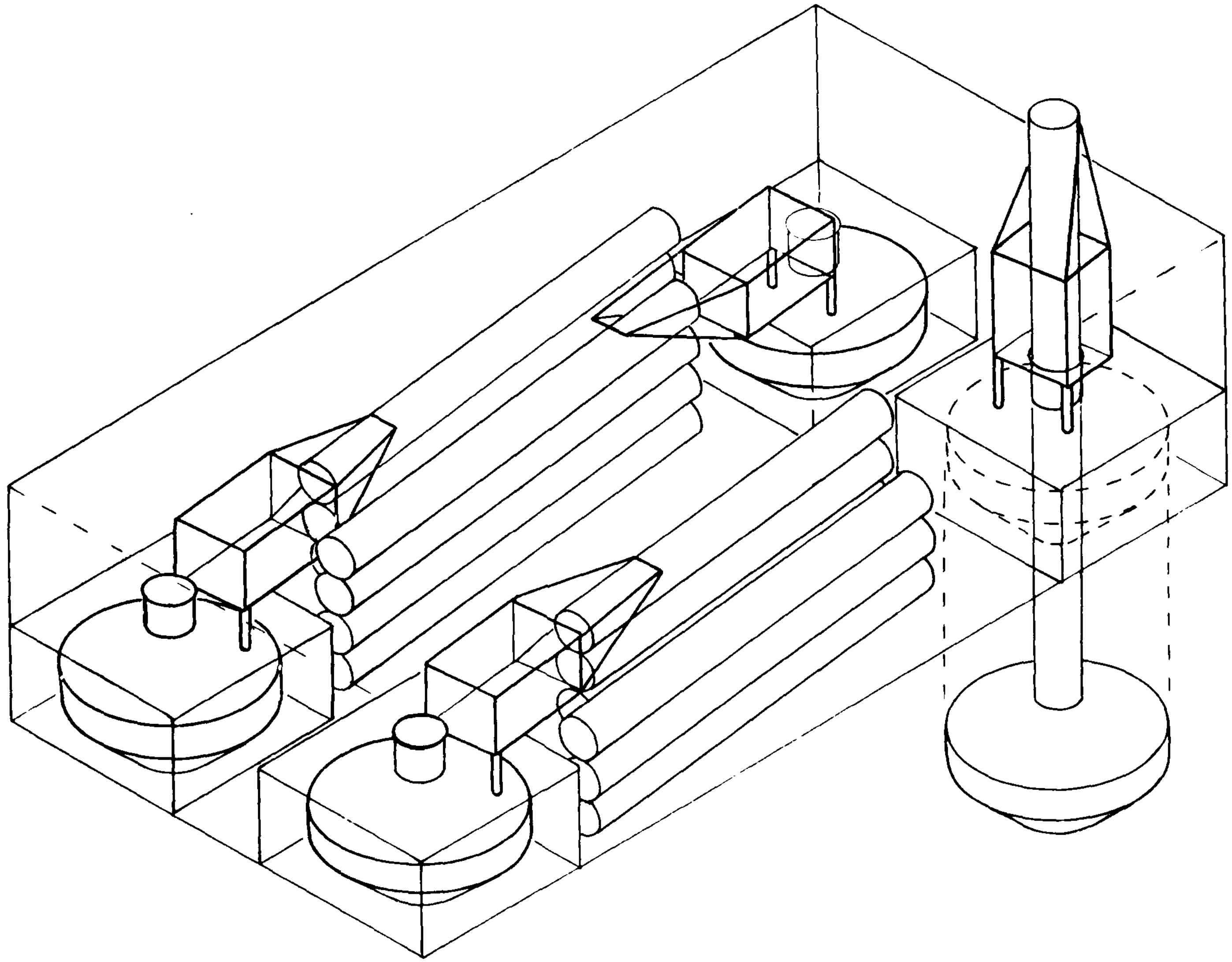

Figure 7. Leg handling mechanism.

A commercial jointing mechanism can be adapted for quickly joining the leg sections together. The device is described as an automatic-lock and mechanical release connector that eliminates time consuming and expensive makeup of large diameter pipe - principally, the conductors used for pumping petroleum fluids from the reservoir to the surface. This automatic joint feature will significantly reduce the manpower, equipment, and logistics associated with joining leg sections during installation.

Footing (Ref 4)

The footing at the base of each support leg allows the jack-up unit to be used in a wide variety of soil conditions. The function of the footing is to penetrate the seafloor and mobilize the available strength using the minimum amount of depth. Figure 8 shows a spudcan footing having a spike attached to the bottom end. The combination functions as a universal footing since the large circular portion has sufficient bearing area to mobilize strength in soft materials and the spike is suitable for penetrating rock and coral. The footing size (12 feet in diameter and 5 feet deep) is selected so that the spudcan will perform during typical operations as well as during sea state 6 conditions. The present analysis shows that the selected module size, leg spacing, and spudcan dimensions are feasible for the ACTF environmental and span loads.

Figure 8 also shows the footing equipped with water jets on the top and bottom. Water jetting permits a deeper penetration of the footing in cohesionless material, thereby reducing the effects scour may have on foundation stability during the operating phase. The jetting system also aids in recovery of the footing when deeply penetrated in soft clay. Tests on a 2-foot model footing indicate that the jetting principle allows the footing to penetrate deeper in sand as well as to decrease the amount of uplift force needed to recover the leg.

Vibratory Pile Driver (Ref 5)

The Navy currently uses temporary pier facilities to transfer cargo over the surf to the beach during amphibious operations. Pile driving is the most time-consuming activity during the construction of these facilities. As part of the ACTF project, a work unit on vibratory pile driving was set up to investigate this technology for both near-term and long-term benefits. The Amphibious Construction Battalions (PHIBCBs) use single-acting diesel hammers to install these piles. A vibratory driver is used to extract the pile during the retrieval phase. Because the PHIBCBs cannot rely on the vibratory driver to drive piles to a specific bearing capacity, two pieces of equipment are necessary to handle pile installation and extraction. A more efficient technique, such as using the vibratory driver to both install and extract bearing piles, would eliminate the requirement for having two pieces of equipment to handle piles, and improve pile installation rates in sand and clay.

Vibratory pile drivers have the capability of significantly decreasing pile installation time, especially in granular soils. However, they have not been widely accepted because of the uncertainty in estimating the bearing capacity of the driven pile. When driving bearing piles, the standard industry method for obtaining a load-carrying

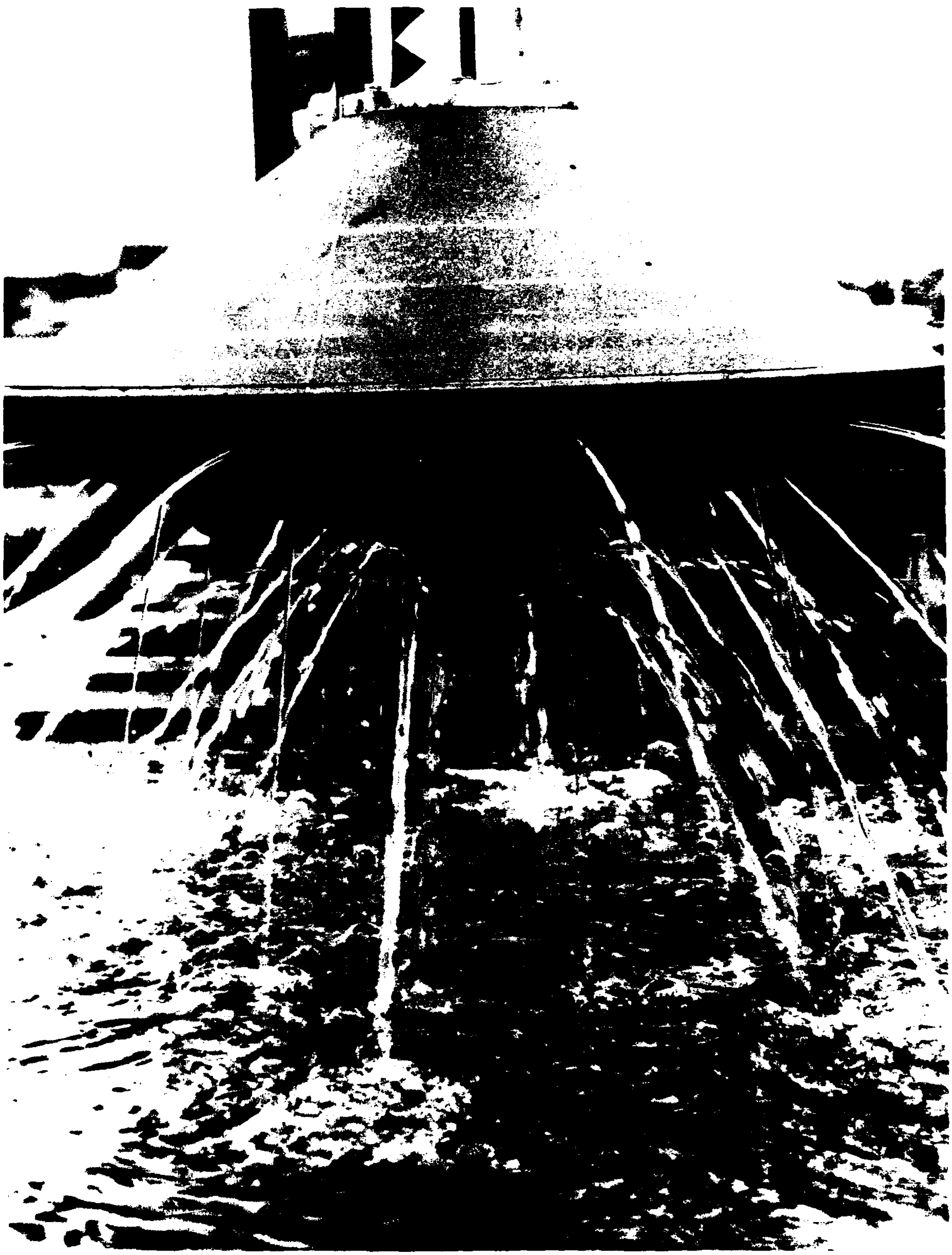

Figure 8. Universal footing.

capacity of a pile installed with a vibratory driver is to check bearing strength with an impact hammer. The advantage of improved productivity is lost with the checking procedure. Currently, there is no other method to predict the capacity of these bearing piles installed with a vibratory driver.

Initial tests of a vibratory pile driver indicate that significant time savings are possible using vibratory pile drivers. Additional work is needed to quantify the time savings and to develop a method of predicting pile capacity.

SPANNING AND CARGO HANDLING TECHNOLOGIES

The spanning and cargo handling systems provide a bridge between the jack-up modules, and a means of loading and transporting the containers from the ship to the beach.

Development of efficient spanning structures for the ACTF led to the first ACTF technology to transition to advanced development and production. The Lightweight Modular Multipurpose Spanning Assembly (LMMSA), an ISO container compatible bridge system, was developed. This system can be launched from one side of a 120-foot gap. This system has been constructed and is currently available for use in repair of a damaged elevated causeway section.

Work on other spanning structure concepts continued. Ultimately, this effort culminated in the development of the ACTF folding span. The ACTF folding spans are a unique design, conceived so that they would provide a very reliable 400-foot span and still be able to fold into a small package for transporting. The final design achieved a greater than tenfold reduction in volume between extended and folded spans.

Another part of the ACTF technology being developed is the automated transfer of containers from the pierhead to the beach. The container mover system will be capable of moving containers weighing 40,000 pounds at a speed of 3 ft/sec. It must also provide fast, safe transportation in all weather and environmental conditions. Recent testing of a linear induction motor, as a means to move containers, has been completed and shows that this type of container transfer system is suitable for the ACTF.

The container hopper, which is a piece of hardware developed in support of the Container Offloading and Transfer System (COTS), has direct application to the ACTF. The hopper was developed for use on floating barges, but its use on the ACTF pierhead will provide the same control of container movement and subsequent speeding up of cargo transfer operations.

The portable container crane was developed as a notional offloading mechanism to be mounted to the ACTF pierhead. The addition of an onboard crane capability would have eliminated the need for berthing two ships and thus would reduce the berthing loads on the system. However, the decision was made early on to utilize the capability of the existing T-ACS crane ships and design the system to cope with the loads of the nested ships. The portable container crane is reported as a development which may still have some usefulness in years to come.

Lightweight Modular Multipurpose Spanning Assembly (LMMSA)

Many of the concepts envisioned for the ACTF require a spanning structure for use either as a basic building block or for repairs. Since the spanning structure could be used in any one of several ACTF concepts, the spanning structure was required to be adaptable to many interfaces and load constraints.

To develop a multipurpose, lightweight spanning structure, two separate contracts were awarded to competitive bidders to determine a configuration for this spanning structure. One contract was awarded to Fairey Engineering, Ltd., a British company experienced in the development of tactical bridges. ESD Corporation, in a joint venture with Merlin Technologies, won the second concept development contract. Fairey elected to develop an aluminum alloy structure. The ESD approach emphasized extensive use of high-strength composite materials to produce a lightweight structure. The Fairey aluminum structure was chosen for advanced development.

Potential uses of the multipurpose structure include Roll On/Roll Off (RO/RO) ship offloading, Elevated Causeway (ELCAS) repair and tactical bridging, in addition to ACTF construction and/or repair elements.

To accomplish logistic objectives, a modular structure, which is dimensionally compatible with ISO shipping containers, was chosen for the development (Figure 9). Three types of modules were developed - two types of end modules and an intermediate module. Of the two end modules, one must accommodate relative motion between the ramp and its support. Intermediate modules, which make up the greater portion of the span, will fit between the various abutments to be spanned (e.g., RO/RO ship and pontoon platform).

Modularity of the design was emphasized to make the structure adaptable to various missions and to simplify logistics and deployment. Desirable attributes for the LMMSA include field repairability, low cost, and low technical risk. These factors combined with basic factors such as mission flexibility, modularity, light weight, deployability, retrievability, and transportability, provided the basis for selecting the final design.

Folding Span (Ref 6)

The approach taken during this research was designed to uncover the best span which could be built with the anticipated technology of the 1990s. The key was to both identify many span concepts and use the correct criteria to select between them. Defining and refining the selection criteria started early in the process and continued right up to the final selection. General categories of span concepts were identified and the number for further development was narrowed. The process for selecting the best span was detailed to ensure the candidate concepts were developed efficiently.

The criteria for comparing ACTF span concepts has evolved as the competing concepts were reduced and refined. Performance thresholds for the most important criteria were proposed together with the concept of a LASH barge as a jack-up pier. These initial requirements were focused on improved rough weather operations and reduced shipping volume. As more span concepts were identified, more specific criteria and a priority ranking were generated to select between concepts.

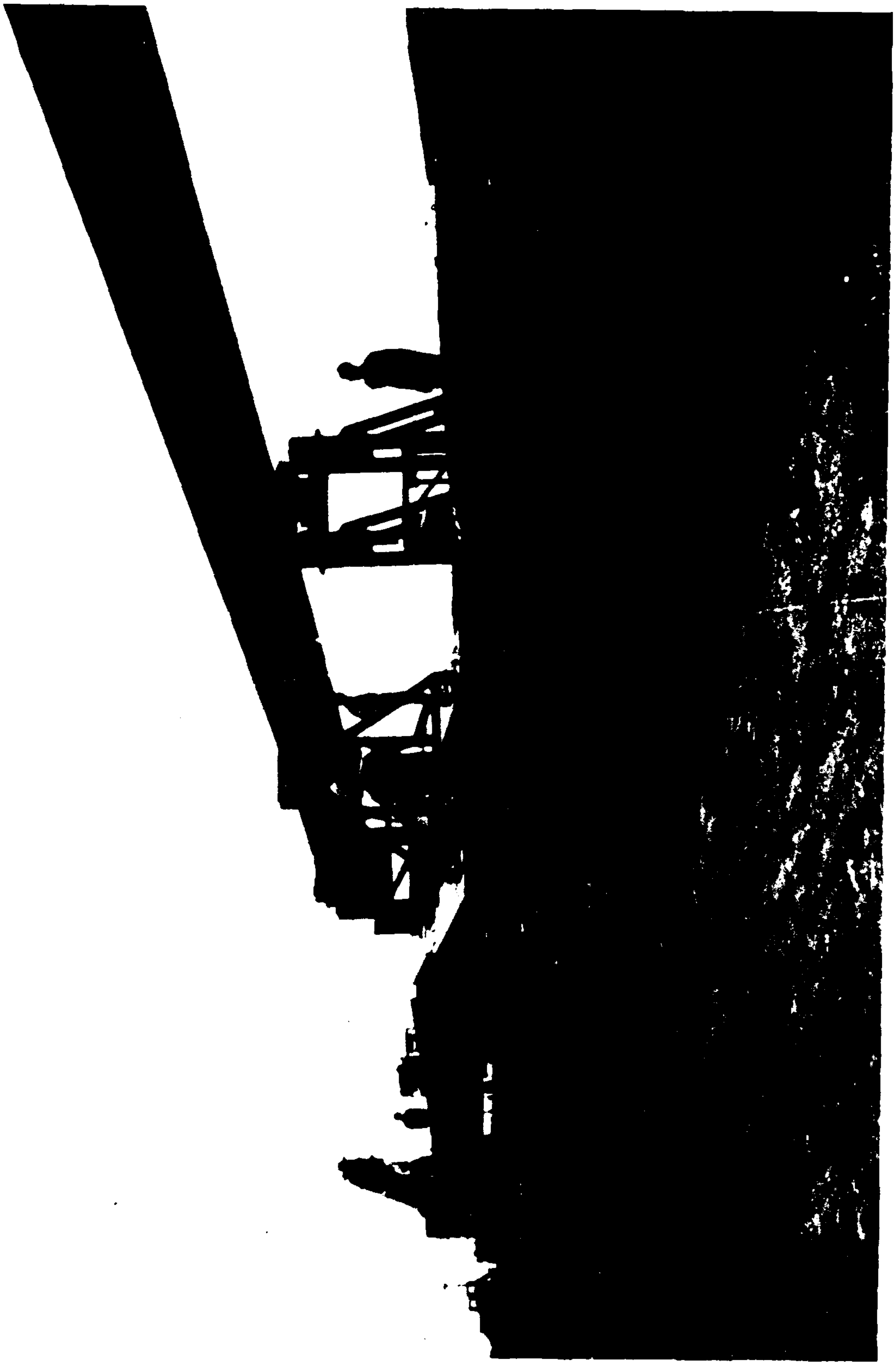

Figure 9. Lightweight modular multipurpose spanning assembly.

Several studies were conducted to ensure the criteria priorities and performance requirements were appropriate. The first study, a parametric analysis of span loads, examined length of individual spans versus the cost of the entire 3,000-foot span. The second study reviewed the compatibility of the competing span concepts and the types of conveyor systems used to move cargo. The third study compared the time to erect a 3,000-foot causeway for each concept.

The parametric analysis indicated that the optimum span length is between 300 and 400 feet. This also appeared to be the longest span that can be folded into a jack-up foundation unit. The optimum length (375 feet) is the same for a wide range of span and jack-up costs, structural materials, and payload or span concepts. The limiting factor is stowing the span inside the jack-up module.

The investigation of the span/container interface demonstrated that the span could not be considered independent of the container interface. A criterion for container interface flexibility was added to the final prioritized list.

The difference in system erection time proved small by the investigation of installation techniques and erection times. All four spans can be erected well within 7 days.

The fundamental period model warns that the span will be sensitive to dynamic excitation from common wind and wave conditions. Dynamic model wind tunnel testing, motion damping systems, and stiffening systems must be investigated.

The Snaplock Truss (Figure 10) best matches the criteria for the Advanced Cargo Transfer Facility, and may also be particularly suited to succeed the Bailey Bridge as a modular span for Army and Marine Corps applications. The TELETRUSS (Figure 11) is a permanent bridge with good shop fabrication, transportation, and erection features. While not suited for this application, the Scissor Span (Figure 12) might be used as a building roof arch or a tool for permanent military and commercial construction.

Linear Induction Motor Container Mover

The linear induction motor container mover will automate the movement of containers from the pierhead to the beach. The container mover is required to have the capability to move containers weighing up to 45,000 pounds at a speed of 3 ft/sec. The load limit is one container per 400 feet of pier. The motors must be able to move the containers under adverse conditions such as track sag, misalignment, and corrosion.

Beginning in 1986, tests were done on several different configurations of the linear induction motor container mover. The basic difference between these configurations was the way the linear induction motors were mounted. Initial testing was done on a rigid side-mounted motor configuration. The motors were rigidly mounted in pairs on each side of the test track approximately 20 feet apart. These motors were first tested using a standard ISO container mounted on Hilman rollers. The motors could not move this container because the gap between the motors and the container was too large (this gap has to be maintained between 1/4 and 1/8 inch for maximum motor thrust to be applied to the container). The rigidly mounted motors were then tested with a container that had a reaction plate mounted on each side. This container did not move smoothly down the track because the variation of the gap distance was between 1/8 and 1 inch, which caused the thrust to vary greatly.

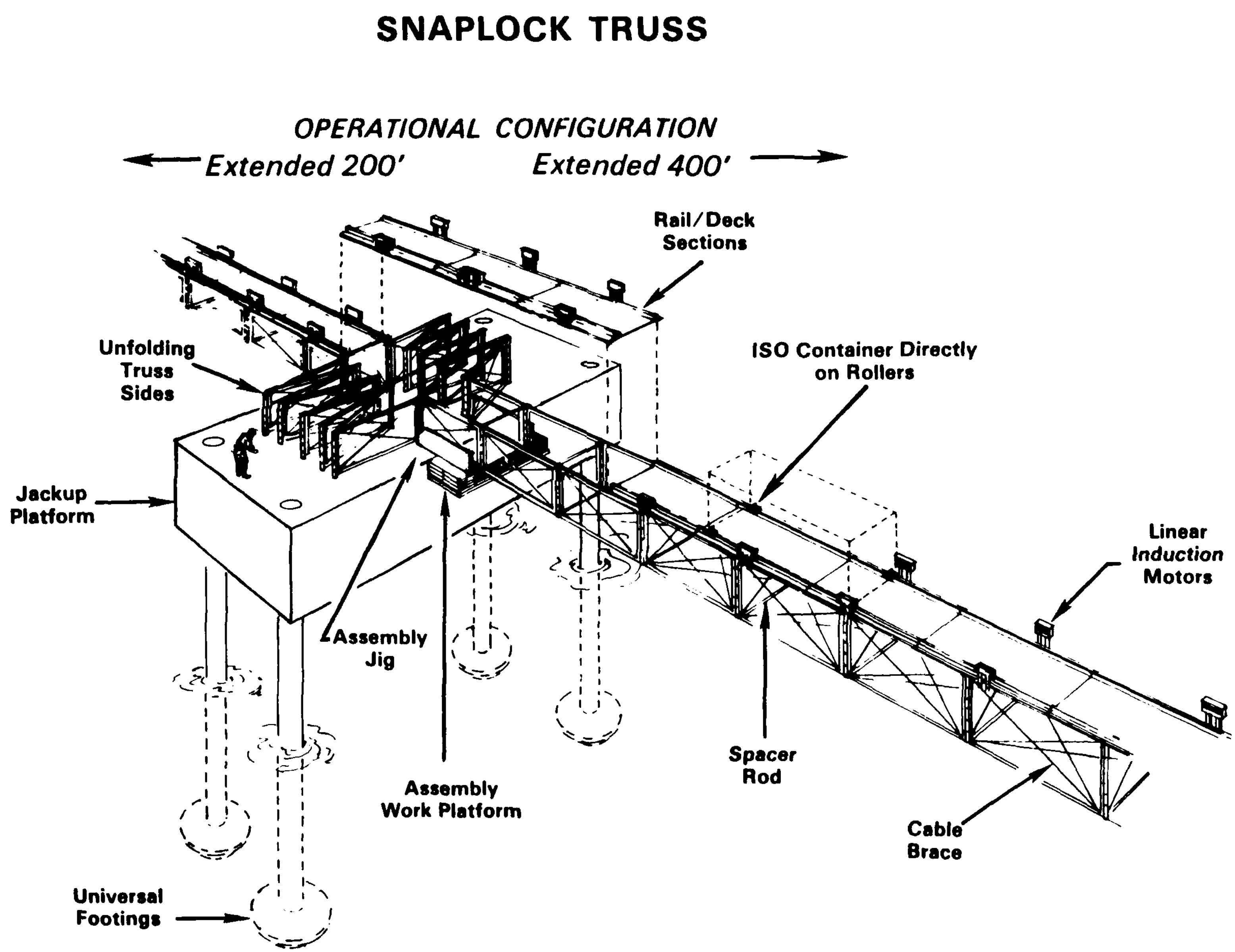

Figure 10. Snaplock truss.

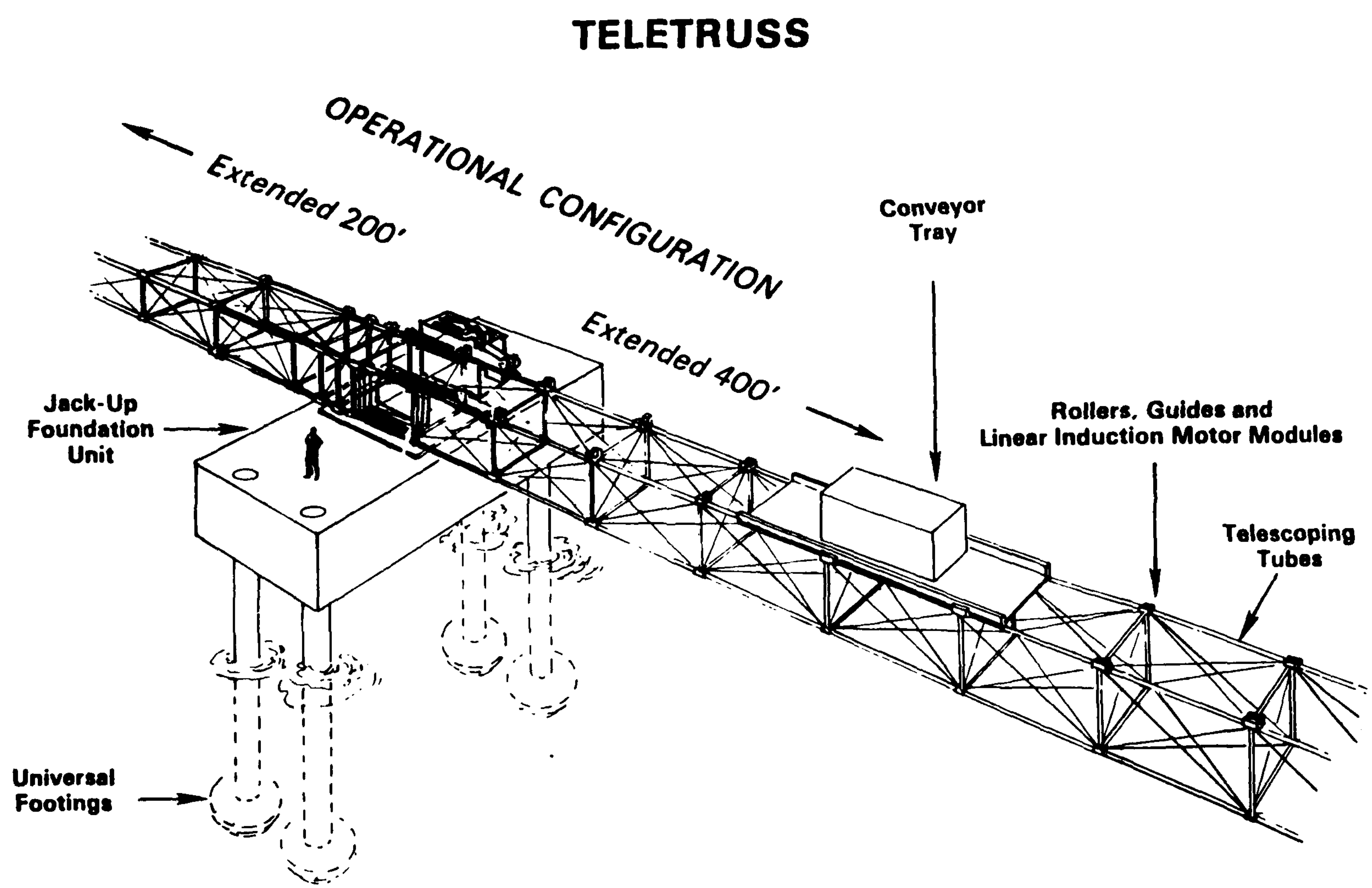

Figure 11. Teletruss.

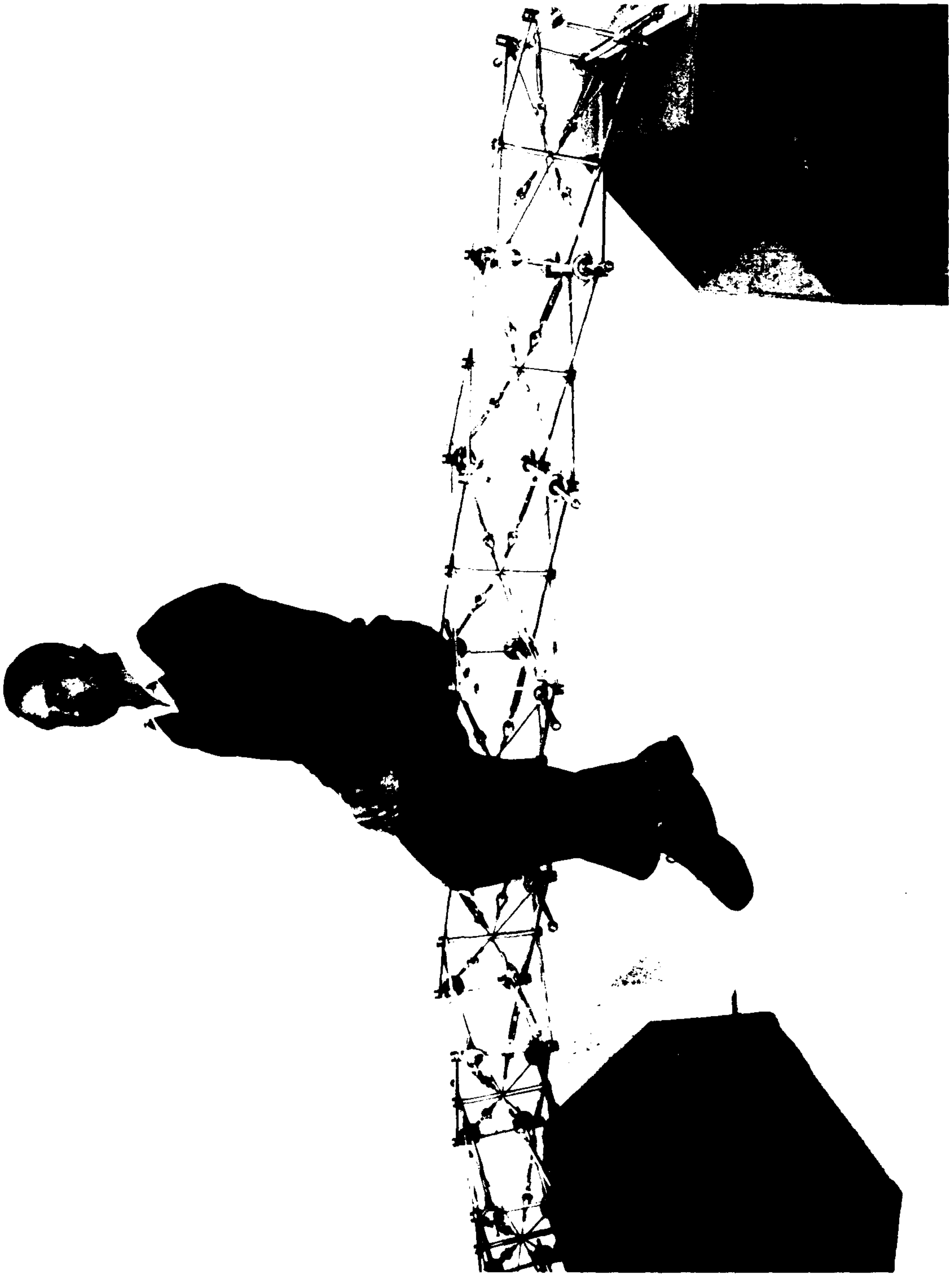

Figure 12. Scissor span.

The second configuration tested consisted of side-mounted, air-actuated motor mounts. The air actuator was used to move the motors in a horizontal direction until the conveyer rollers, mounted on each side of the motors, were touching the reaction plate. This maintained the gap between the motors and the reaction plate. However, the side rollers began sticking as the container moved down the track. These side rollers are designed to guide the container down the track keeping the rollers parallel to the track at all times. The binding of these side rollers inhibited the motion of the container, causing it to move erratically down the track.

The final configuration of the container mover consisted of mounting the motors between the rails of the test track and mounting the reaction plate on the bottom of a cart on which the container was placed (Figure 13). The motors were placed in pairs at 20-foot intervals between the rails of the test track. They were mounted on springs and had rollers on each side to reduce the friction and control the gap between the motors and the reaction plate.

The test data show that the motors are capable of moving an 8- by 8- by 20-foot ISO container that weights 30,700 pounds along a 100-foot test track at a maximum speed of 6 ft/sec. Calculations based on these data show that the linear induction motors have the capacity to move containers weighing 51,000 pounds at speeds in excess of 3 ft/sec. The motors tested have been exposed to the ambient environment (Port Hueneme, California) for about 3 years with no adverse effects.

The advantages of this system include smooth operation and large capacity. The previous system, where the motors were mounted on the side of the track, caused the container to jerk and to rock back and forth when moving down the track. The present system allows the container to move smoothly down the track in either direction. Another advantage of this system over the previous one is ease of installation. The motors and track can be built in sections that can be easily installed in a short period of time.

One adverse characteristic of the motors is that they will continue to accelerate a container until its speed is near the motor's synchronous speed. This causes the system to exceed the ACTF speed and load limitations. Some form of speed control must be used in conjunction with the motors so that the containers' speed and the spacing between them can be controlled regardless of their weight.

Controlling the speed of the container will affect the efficiency of the motors. Maximum efficiency occurs when the speed of the container is near the synchronous speed of the motors. If the motors are controlled so that they are forced to move the container at a speed of 3 ft/sec the efficiency will be low, probably as low as 4 percent.

Further improvements to the present system would include the testing of a speed control system. This type of system has already been developed and would only need minor modifications to be applicable to the container mover. Further development of the cart on which the container is mounted needs to be completed. The present cart is too heavy to be handled easily without lifting equipment. An ideal cart would be one that could be lifted and moved without the use of lifting equipment. An emergency braking system needs to be designed and tested. This system could be incorporated into either the cart or track design. The final development would be to completely modularize the container mover system to make installation quick and easy.

Figure 13. Linear induction motor container mover.

Hopper

The hopper, designed originally to be used at sea, is mounted on the ACTF as shown in Figure 3. When in operation, the hopper-equipped ACTF is moored to a crane ship which in turn is moored to a containership (see Figure 1). A cart will be positioned under the hopper, as shown in Figure 3. The crane will remove a container from the cell or deck of the containership and lower it down through the hopper and onto the cart waiting below. Figure 3 shows such a loading.

The hopper will do at least three things to facilitate placing the container onto a cart:

1. Present a large target for the crane operator as he lowers the container.

2. Stop any horizontal movement of the container which may occur due to movement of the vessel supporting the crane.

3. Maintain the container directly over the cart as it is lowered into position.

In the only time it was used at sea, the hopper was successfully tested as a part of the OSDOC II operation which took place in October 1972. A containership was anchored approximately 1 mile off the beach at Fort Story, Virginia. A DeLong barge was moored next to the containership and the hopper barge moored to the DeLong. A 250-ton capacity P&H truck crane was mounted on the DeLong.

There were three primary design criteria for the hopper. First, it was decided that the system would arrest the movement of an 8- by 8- by 20-foot container weighing 44,800 pounds moving at a maximum horizontal velocity of three feet per second. Second, it was decided that, in arresting the motion, the container would not be damaged by the hopper system upon impact. Finally, the hopper had to be capable of guiding the container squarely onto a trailer parked below.

The 3-ft/sec maximum velocity was chosen before the hopper was built. It is an arbitrary figure which most observers felt was a good approximation of the maximum velocity at which a container would swing at it was suspended from a crane. For example, if the container was suspended at the end of a 150-foot line, it would have to swing through an amplitude (1/2 swing) of nearly 7 feet to reach 3 ft/sec at the point of maximum velocity (the bottom of the swing). This is a relatively large swing, particularly if taglines are used to restrain the load. In addition, crane operating practice dictates that the load not be allowed to swing out from under the boom tip.

Adding these factors together, it was concluded that the containers would not strike the bumper at more than 3 ft/sec. This proved to be a conservative estimate because in all loadings during operational tests using the barge crane (OSDOC II) and afterward, the containers had little horizontal motion if the crane was not swinging the boom.

Portable Container Crane (PCC)

A critical element of the ACTF system is a crane that lifts cargo from the ship to the pierhead of a transfer structure. This crane has been designated the Portable Container Crane (PCC). Both floating and fixed cranes were considered as candidate systems. Although the floating T-ACS crane ship was the eventual choice, the fixed crane was considered and is reported here.

Cranes performing a similar function to PCCs in developed ports are typically rail-mounted gantry cranes capable of moving as many as 48 containers per hour. These permanent cranes are designed to operate in well-known environments compared to cranes designed for use in expediently constructed cargo transfer systems. The PCC must operate in a wider range of environments less well-known in local effects. At the same time, container throughput is no less a consideration in the PCC.

The ACTF would use four PCCs operating from two pierheads which feed a common cargo transfer facility. One design goal of the ACTF is to transfer approximately 10,000 8- by 8- by 20-foot containers and 2,700 wheeled vehicles from non self-sustaining (NSS) vessels to partially developed beach between D+5 and D+15. As analyses below will show, this requires four cranes, each capable of transferring at least 250 containers per day from NSS ships.

The number of cranes required to maintain throughput is related to the variables of crane weight, crane erection time, and shipping volume. A single large crane would be too heavy for expedient founding and would not be sufficiently fast in discharge rate for vessels alongside. The single large crane would similarly not be easily transported and erected.

In order to expedite cargo transfer beginning on D+5, it is necessary in the ACTF for the PCC to be stowable in the containership's 40-foot long by nominally 50-foot deep by 8-foot wide cells, and to be erectable from the containership to the offshore spudded or founded pierhead by means of a portable crane carried on the containership. The containership carries all the elements of both the crane and transfer systems. This technique reduces double handling and is the most economical usage of vessel tonnage. Further, it is time-expedient. Accordingly, the PCC design allows the reduction of all PCC components to stowable lengths and manageable weights by placing each component within the ISO (Ref 3) container design envelope for geometry and weight. Construction time for each PCC must take fewer than 72 hours. Therefore, pinned connections are used and self-erection techniques are designed into the PCC structure to facilitate placing it in service within the requisite time.

A review of the literature from numerous United States and foreign manufacturers of gantry-type, pedestal-mounted luffing and slewing-type (whirley) and hydraulic boom-type cranes was performed. This review considered:

1. Lifting capacity.

2. Boom reach.

3. Crane weight.

4. Duty cycle speed.

5. Amenability to rapid erection and easy carriage.

Preliminary requirements analyses of these relationships indicated that the maximum outreach for a container discharge crane is determined by three variables:

1. Vessel beam.

2. Distance between platform and moored vessel.

3. Crane structure.

Consider a large NSS vessel with a 110-foot maximum beam. Allowing 38 feet from the crane centerline to the side of the ship requires a boom radius of 150 feet to reach the furthest container in a three-hatch array. Elevation of the crane is governed by the height of the container stack, reasonably assumed to be 80 feet above the platform. These dimensions require a crane machinery deck approximately 75 feet above the top of the platform. The center-to-center distance between two cranes must exceed 90 feet because of erection constraints described in the next chapter. Vessel hatch length is assumed to be 40 feet with a 12-foot interhatch separation.

According to ISO rules, Type C Dry-Van Closed Containers have a maximum gross weight of 44.8 kips. To lift and rotate the container as required in the ACTF concept, a spreader beam is necessary. These rated loads are given in Table 1.

Table 1. PCC Rated Loads in Kips

Item	Weight
ISO 20-foot dry-van container	44.8
Spreader beam (estimated)	5.2
Total rated load	50.0

An analysis of the duty cycle of the crane requires evaluation of throughput and other ACTF requirements. Approximately 10,000 containers must be discharged from a ship and moved ashore over a 10-day period. The conceptual ACTF system uses four container unloading cranes on two pierheads. Therefore, each crane must be capable of unloading 2,500 containers in 10 days or an average of 250 containers per day. Assuming 20-hour working days, an average of 12.5 containers per hour must be unloaded. In other words, a maximum of 4.8 minutes per container can be allowed for one operating or duty cycle. This does not include the time to backload the vessel.

The lightest crane meeting reach and duty cycle requirements is a luffing and slewing portal-mounted lattice boom crane. The notional PCC is mounted on a portal which is pinned to a foundation (platform) -- whether platform driven piles or jacked piles. These cranes have performed well in American President Lines, Ltd. operations in Subic Bay, P. I., where, in fact, a throughput decrement occurred when they were replaced with conventional container gantry cranes.

To achieve the required positioning at the vessel hatch, gantry-type container cranes travel transversely on a railway system. This transverse movement of the entire crane is dependent on the lateral movement of the cargo in the working hatch. Cargo work stops when the crane moves transversely for repositioning. In the ACTF system, the vessel moves to position hatches, which means that the crane must be able to work three adjacent hatches without moving the vessel. Given two PCCs to the vessel, six hatches can be worked without moving the vessel. This arrangement keeps throughput at a maximum rate.

The crane most nearly capable of meeting the design objectives for PCC, and most amenable to the redesign of its various components to meet all requirements of PCC, is a lufting and slewing portal-mounted lattice boom crane.

Floating Containers

One ACTF concept investigated was to offload containers directly into the water, then push or tow them ashore. The idea of floating a container was considered in the past and a test was conducted at another laboratory with inconclusive results. The ACTF project explored the feasibility of floating containerized cargo from ship to shore after an assault landing (Figure 14). To accomplish this task, the following two criteria must be satisfied:

Figure 14. Floating containerized cargo.

1. Render the container watertight, thereby keeping the contents dry.

2. Provide stability to an inherently unstable item.

The results from the various tests show that waterproofing a container and providing stability can be accomplished in a single system. A polyurethane baggy with flotation stabilizers satisfied the two criteria: keep the container dry and provide stability. All other tested waterproofing methods failed to satisfy the criteria. Results from the tow and beaching tests indicated that towing a floating container can be easily done using a small dedicated tug or barge; however, beaching a container once it reaches the shore is an unresolved problem. When pulling a loaded container up onto a beachfront, it is possible to part a line because of high tension loads, and it is also possible to damage the waterproofing medium so that it could not be used a second time without repairs.

The floating container concept, though feasible, is not considered to be a viable candidate for the ACTF. However, the concept may prove to be an excellent method for supplying a limited amount of cargo in a small-scale operation, or it could be used to transport a minimal amount of supplies while the ACTF is being installed. Test results from the polyurethane baggy with flotation stabilizers show that this method worked quite well.

MOORING TECHNOLOGIES

The ACTF mooring system consists of a berthing and mooring system, whose major components are lines and anchors, mooring modules, and portable dolphins.

Ships must be brought to the berth without tugs. The tug's function is assumed by several barge-like mooring modules, which are essentially mooring buoys that contain winches for the mooring lines. Eight mooring modules are shown in Figure 1. An arriving ship picks up and secures a line from a turning module (buoy) seaward of the berth. Other lines are passed from appropriate mooring modules, and the ship is eased into position by winching.

Loads on the ships cannot be allowed to pass to the legs of the pier. Rapidly-installed dolphins are included in the system to resist horizontal loads imposed by the ships at times when mooring lines must be released. Two dolphins are shown in Figure 1.

Current Loads on Ships Moored in Shallow Water (Ref 7)

Once the initial conceptual design for the ACTF was accomplished, it was clear that assessment and further development of the concept required an improved understanding of the loads to be dealt with in the design of the mooring system - particularly the forces and moments exerted by a current on the ships stationed at the facility. Of special interest were the increase in the drag that is associated with shallow water, and the loads that occur when two ships are moored side by side. The question of current-induced motions of the ships also was raised.

Ordinarily, high winds and locally-generated storm waves tend to persist a few days. Moderate to high swells from distant storms may persist a few days or somewhat longer. To avoid excessive forces or motions from these causes, the ships may go to sea temporarily. If, however, a strong current exists where the ACTF is to be located, it is likely to be a daily occurrence. Daily departures and returns are not acceptable; thus, it may be necessary to cope with large current forces. In view of the large current speed anticipated, 4 knots, current forces were considered first in assessing the ACTF conceptual design.

Two design goals of the ACTF are to minimize the rolling of the ships (for crane operations, roll is especially troublesome), and to minimize the length of the pier. In the system presently under consideration, the hypothesis is that roll motions can be reduced sufficiently by heading the ships mainly into the waves (swells). This orientation could place the ships broadside to the current. Moreover, because minimum length of the pier is an objective, the ships will be located in shallow water (depth-to-draft ratios usually between 1.5 and 2.0), where the force of a beam current is increased considerably through the "blocking effect." Thus it is necessary, in design, to consider forces whose steady component is very large. For this reason, especially, good information on current loads is required early in the design process, when important trade-offs and other decisions are made.

In a series of tests conducted at the Danish Hydraulic Institute, the craneship was assumed to be the T-ACS-1, a lengthened and modified <u>Mariner</u>-class vessel, and the containership was assumed to be a C5 of the <u>Export-Leader</u> class. The tests were approached cautiously and systematically. The flume was made wide enough relative to the ship to

avoid having the measured forces include the effect of the nearness of the side walls, yet flowrate was sufficient to avoid unacceptably low Reynolds numbers. There was no effect of varying the Reynolds number over the range used in the bulk of the tests. Standard practice is to perform the tests with the hulls fixed. There was a question as to whether, in the special conditions of shallow water, the local hydrodynamic field would create forces that would cause oscillations of the ship if it were free to roll and yaw. First indications were yes. But the test support conditions were not realistic. So Phase II of the program included tests of ships realistically moored.

Phase II of the tests also was conducted systematically. Tests were made of one ship, with the current broadside and also at various angles of incidence. These tests provided two things: (1) the opportunity to continue comparing the new moored-ship data to data by others for fixed models, and (2) data for single ships at the ACTF in the situation where they are being maneuvered around by winches and being exposed to various angles of the current. The last tests dealt with two nested ships moored broadside to the current. Data were obtained on the lateral force coefficent (Figure 15) and the yawing moment coefficient (Figure 16) on the T-ACS-1 for the depth assumed for the ACTF berth. The variations that occur as the relative drafts and the relative positions of the ships vary will provide a basis for design of the ACTF mooring. (In the Phase II tests, oscillations were not observed; however, the lateral force and yawing moment coefficients disagreed with data for fixed models, in that there was a dependence on velocity which did not appear in fixed-model tests. This effect still needs investigation.)

Propellant Embedded Anchor (PEA) Rock Fluke

Propellant Embedded Anchors (PEAs) have been developed for anchoring in situations where conventional anchors are difficult to use or will not meet mooring requirements. These anchors are being used because they:

1. Reduce the shipping burden and mooring scopes.
2. Handle easily.
3. Install precisely without dragging to set.
4. Have both vertical and horizontal holding capacity and function in different types of seafloors (sand, mud and coral).

A PEA that is suitable for anchoring in rock seafloors was developed to allow an increased number of site options. Various model fluke shapes have been investigated in a range of rock types and a conical fluke shape has been selected for further development. A prototype conical rock fluke was designed to fit the existing 20K propellant embedded gun/reaction vessel. The ballistics of the gun and the weight of the projectile were designed so that the projectile would reach a speed of approximately 400 ft/sec before entering the rock seafloor. This speed is based upon previous PEA testing of the sand, mud, and coral flukes.

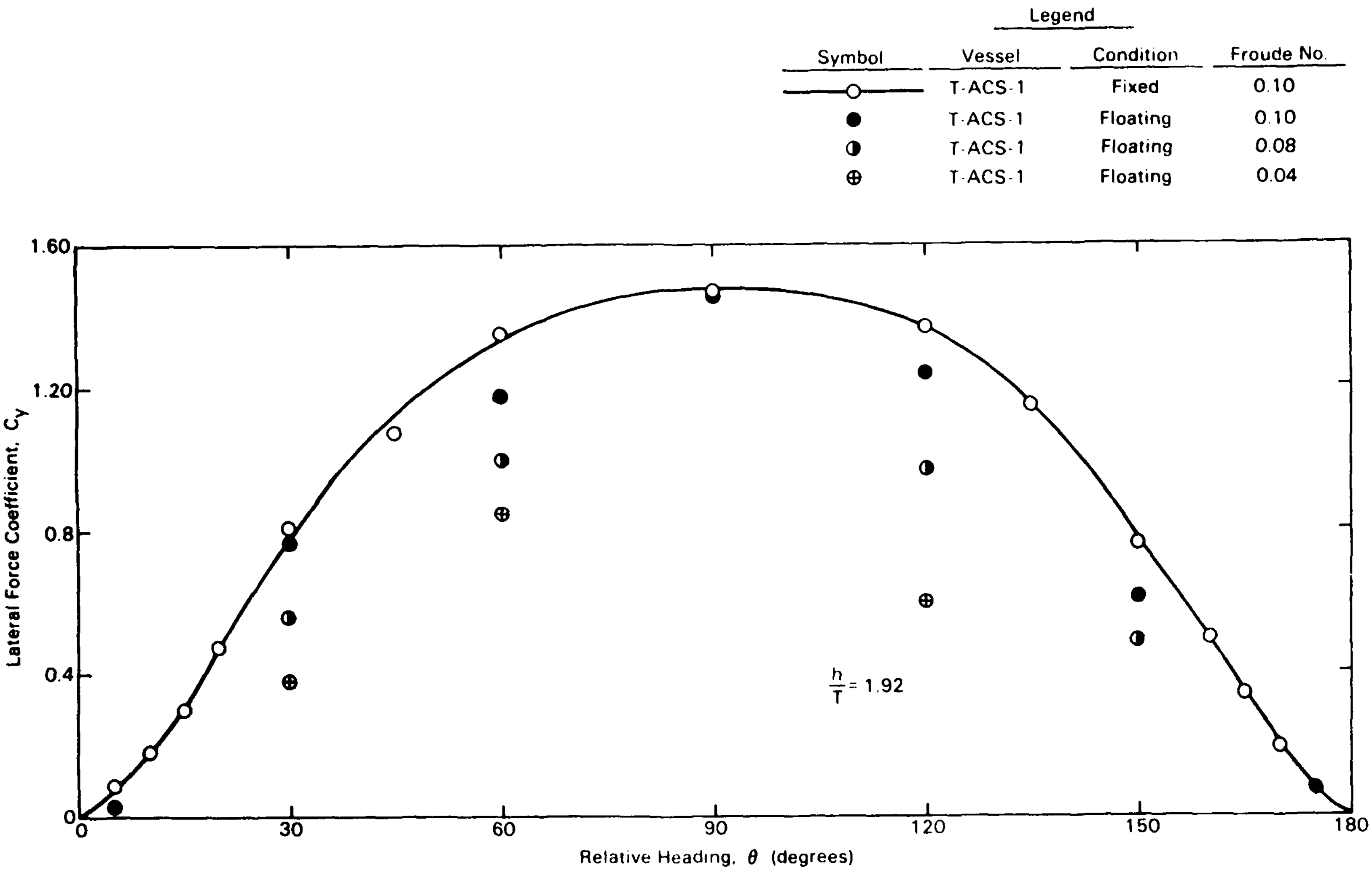

Figure 15. Lateral force coefficient.

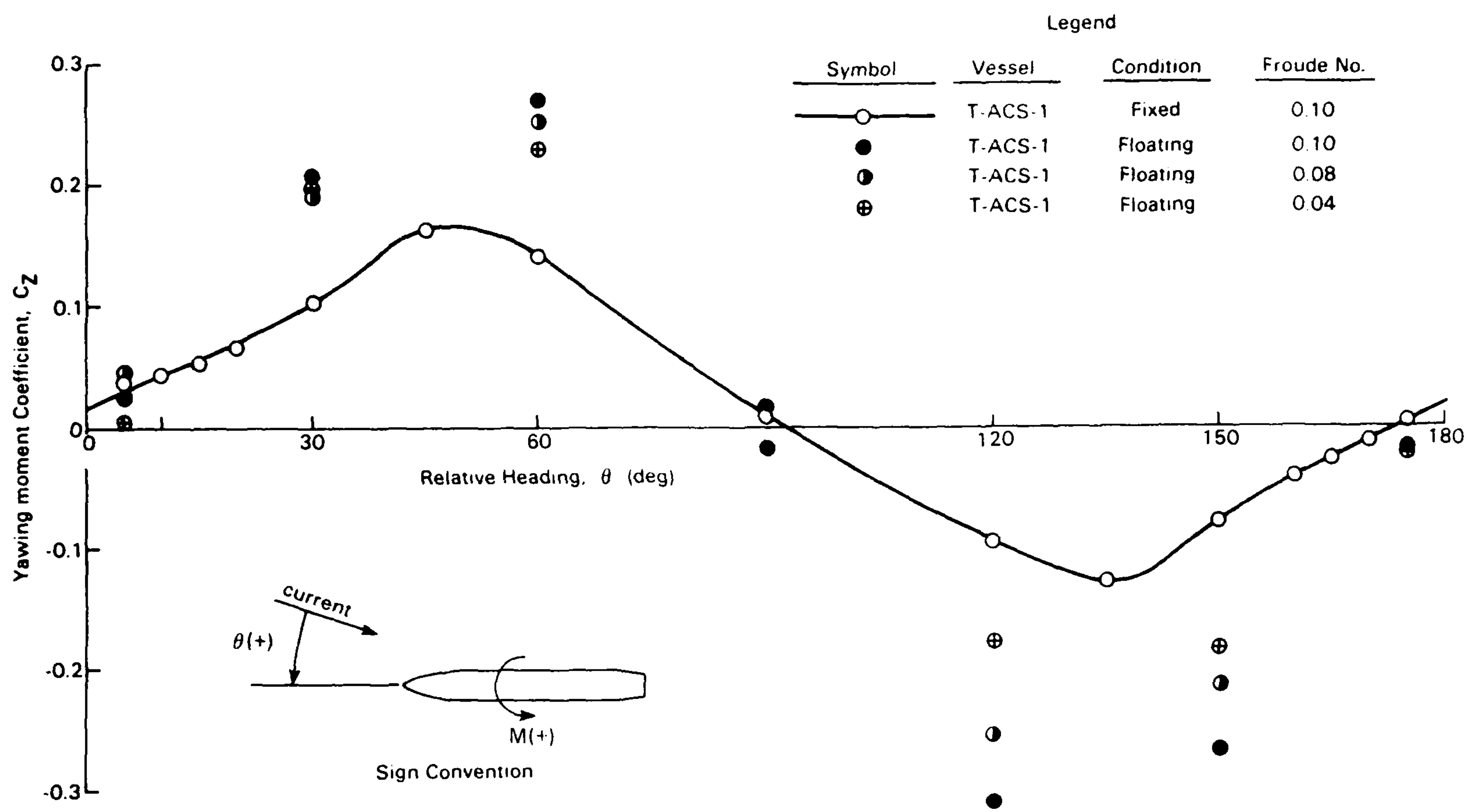

Figure 16. Yawing moment coefficient.

After the selection of the fluke shape and the fabrication of a 20-kip prototype, testing was centered on determining the holding capacity of the anchors in different rock types and under different loading conditions. Initial testing of the rock fluke was done to determine the ultimate vertical holding capacity of the fluke under static loading. These tests consisted of static vertical pull tests.

Because the actual loading of the anchors in expected applications would not be pure static loading, further tests were done to determine the holding capacity of the anchors when subjected to dynamic loads (cyclic lateral loading). Minimum performance evaluation criteria consisting of both a load and an endurance requirement were established for the rock fluke under dynamic loading. The load criterion was based upon the previously established safe working load of the mud fluke (20 kips with a safety factor of two). This is the lowest holding capacity developed by the three existing PEA flukes (sand, mud, and coral) and it is desirable that the rock fluke at least match this performance.

An endurance criterion (the time period for which the anchor will remain installed when subjected to dynamic loading) is needed because the rock fluke is to be used for semipermanent moorings. These two requirements, a safe working load of 20 kips (safety factor of two) for a 6-month time period, are the minimum performance evaluation criteria against which we analyze the data collected from the dynamic testing of the rock anchor fluke.

The dynamic testing of the fluke consisted of short-term tests, 12 to 24 hours, and intermediate term tests, 6 to 12 days. The short-term tests were designed to determine the ultimate holding capacity of the anchors under a dynamic load. The flukes were cyclically loaded beginning at a low load range, from 20 to 30 kips. This load range was increased until failure occurred. The intermediate-term tests were designed to determine how long the anchors would remain embedded under a dynamic load. The flukes were cyclically loaded between an average minimum of 20 kips and an average maximum of 40 kips until failure occurred.

All tests results show inconsistencies. Rock properties can change drastically from test site to test site. It is possible that the data are not consistent because of the effects different rock properties have on anchor holding capacity. To determine these effects, a basic research initiative was started to develop rock mechanics relationships that describe the penetration and extraction of the anchor flukes. This research will help identify the effect of different rock properties on the holding capacity of the anchor. Once this is known, the data can be reevaluated.

The anchors were tested in two rock types, basalt and sandstone. These rock formations are located offshore Anacapa Island, California (basalt) and offshore San Nicolas Island, California (sandstone).

The anchor test conditions can be considered severe in that the cyclic loads applied to the anchors were high period loads and were frequently at or above their minimum performance evaluation criteria. These loading conditions were designed to fail the anchors. Anchor loading in a realistic situation would not be this severe combination of high, frequent loads. One example of this is the mooring of large objects. Large objects respond only to long period waves; the small period waves do not significantly load the anchors. This would result in a loading situation in which the frequency of loading is low and the magnitude of the load

is high, up to the anchor's maximum capacity. This is less severe than our test situation, indicating that anchor performance in a realistic situation would be better than that predicted by the test results.

With the present database we cannot conclusively determine the maximum holding capability of the conical rock anchor fluke or whether it can perform at or above the minimum performance evaluation criteria. The data we have now indicate that the anchor will perform well in long-term testing, but we do not have enough data for statistical significance.

Mooring Module

The mooring of a ship next to a pier, broadside to a current is an unusual event, especially without the aid of tugs. Thus, it was necessary to develop a procedure for getting a ship into and out of a mooring, broadside to the current. The concept developed is feasible, but untested. Normally, a ship will make a parallel approach to a pier, under power (into any currents), and use either tugs or thrusters to move it laterally to the pier. Since the design constraints do not allow the use of tugs, and the ships involved do not have thrusters; this normal type of approach and docking will not work. The ACTF concept is based on the multiple buoy mooring (MBM) technique. The ACTF mooring consists of a turning module, a series of port mooring modules (three for 900,000-pound capacity), a series of starboard mooring modules, and a bow and a stern module. Figure 17 shows the general arrangement of the modules and how the containership is brought into the mooring, after the T-ACS is in position. The containership approaches the turning module, using the 500-foot-wide approach lane, at or just before slack tide (before the current develops from the port side of the ACTF mooring), and moors to the turning module. A line is passed from the stern module. Then, using the winches on the modules and the ship's main propulsion, the ship is warped into a position somewhat parallel to and to the left of (up-current from) the spanning structure. The lines from the port modules are passed and made secure, and at the same time the bow line and breasting lines from one T-ACS are passed. Using the berthing lines, the containership is warped into position next to the T-ACS. The T-ACS and containership are held off the spanning structure by the mooring lines and the dolphin system. The T-ACS would be moored using the same procedures. While the second ship is being moored, the current-induced load normally taken by the port berthing lines must be taken by the dolphin system. The ship is taken out of the mooring in the reverse of the mooring procedure. In case of emergency the two ships may be removed from the mooring during any phase of the tidal current. Assuming the current is at its maximum from the port side of the spanning structure, the procedure would be as follows:

1. Using the port modules, both ships would be warped away from the spanning structure.

2. One of the lines from the turning module would be passed from the containership to the T-ACS. Using this line and ship's propulsion, the T-ACS would release from the containership and swing its bow into the current. It would then release the turning module line and steam away.

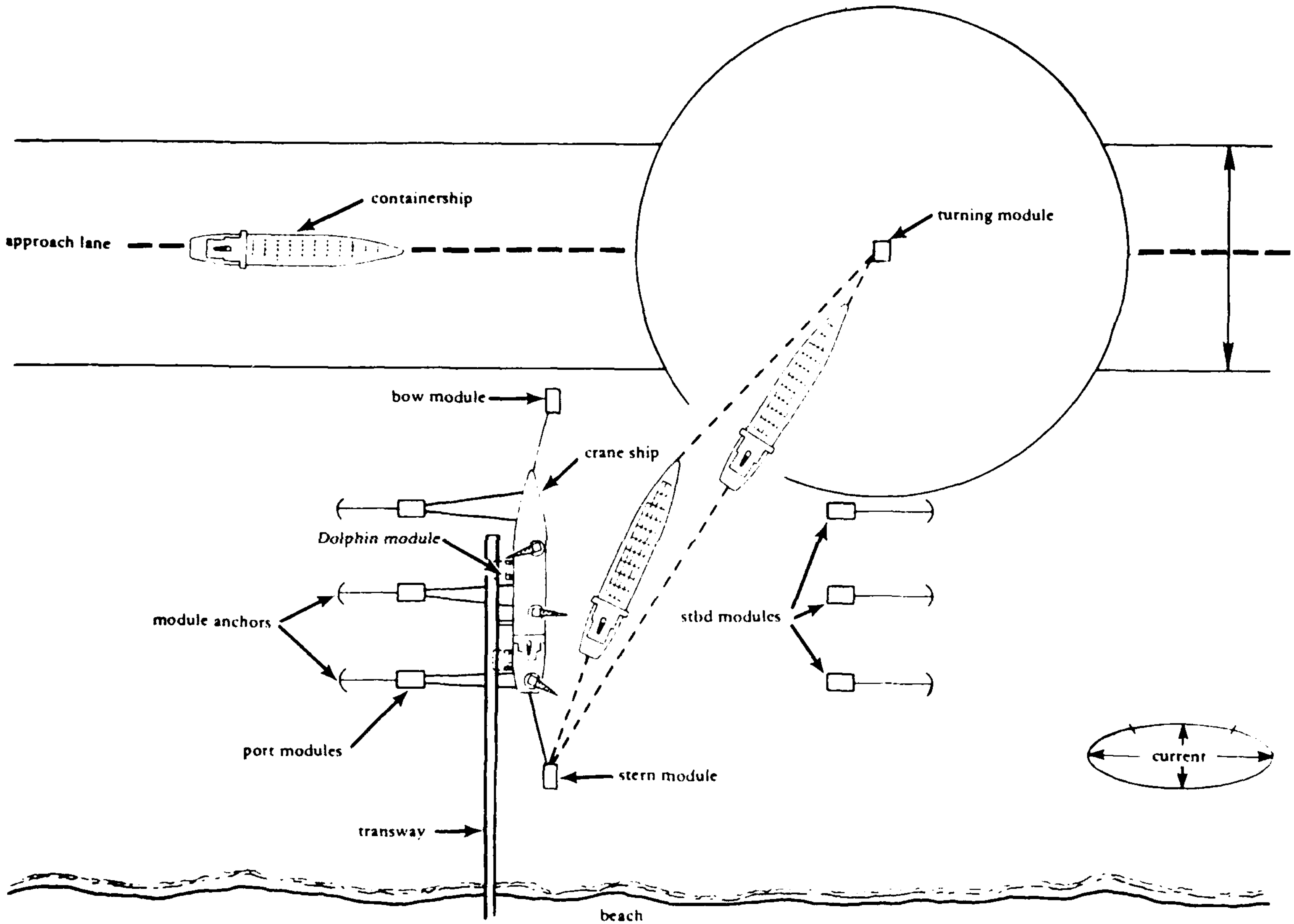

Figure 17. Mooring diagram.

3. The containership would depart in much the same way.

If the current was from the other direction the starboard modules would be used to move the nested ships down current, away from the spanning structure. Then the containership would release and swing on the turning module. This scenario requires that the turning module be able to resist omnidirectional loads, but its load-carrying capacity does not have to be as large as the other modules. In developing the various concepts a special design was not laid out for the turning module as it was felt that it could be accomplished using available technology, such as three-legged single-point mooring using smaller anchors, or using the existing 100K propellant embedded anchor.

Mooring Dolphin

To select an optimum dolphin system for ACTF, several dolphin concepts were identified and evaluated, including: pile cluster dolphin, sheet-pile dolphin, closed-box concrete caisson, floating module dolphin, tension-leg dolphin, and gravity-base dolphin. Each candidate dolphin was evaluated with respect to the following selection criteria:

1. Rapid installation: The time required from launch to operation must be short (tentatively 48 hours).

2. Seafloor compatibility: The dolphin system must be compatible with most seafloors: clay, silt, sand, gravel, coral, or rock.

3. High mobility: The dolphin must be quickly transported by and launched from a Lighter Aboard Ship (LASH) ship. The limitation of the ship's gantry is as follows: lifting capacity, 500 kips; and dimensions, 30 by 60 by 30 feet.

4. Retrieval and reuse: The dolphin must be quickly retrievable for reuse.

5. Minimum field activity: The field activity, including fabrication and construction, must be kept to a minimum. A crew of six persons (tentatively) are provided per shift for the dolphin installation.

6. Rigidity: The maximum dolphin deflection is 15 feet.

The above selection criteria is mainly focused on the feasibility and performance of a dolphin to be used for the ACTF. In addition, some nonperformance considerations such as the fabrication cost, storage space, and reliability during deployment are also included in the engineering assessment and trade-off study. The trade-off study concluded that the gravity-base dolphin is the best choice for ACTF, and it was selected for further stability analysis and structural design.

Prior to conducting structural design for the gravity-base dolphin system, dolphin stability from launch to operational use was investigated. This investigation was to ensure that the dolphin was not fatally flawed

due to lack of stability. The results of the stability analyses (including floating stability, lowering stability, and in-service stability) indicate that the dolphin is stable from launch through tow to the designated site.

Stability decreases while the dolphin is being ballasted and placed on the seafloor. Increase of the ballast load results in reducing static stability.

As sea water is added above the 6.5-foot ballast height, the dolphin base will gradually sink to the seafloor. Forces derived from current and waves will contribute to the dolphin's tilting and drifting. This can be eliminated by the use of control lines and controlled ballasting. The controlled ballasting can be achieved by pumping sea water to the compartmentalized tanks of the dolphin base.

The major concerns for in-service stability are sliding, overturning, and foundation failure.

A sliding stability analysis indicates that sliding failure would occur if the gravity-base dolphin deployed on the seafloor is subjected to a ship force of 500 kips without PEAs. The factor of safety against sliding is greater than 1.5.

The sliding resistance was calculated without considering other types of soil resistance including: front resistance, side resistance, and suction developed upon pulling. Ignoring these different types of soil resistance yields a conservative factor of safety.

Pure overturning would occur if a dolphin is subjected to a ship force of 500 kips without PEAs. To prevent dolphin overturning, the PEAs must be installed to provide both uplift and horizontal resistance. A factor of safety against pure overturning is about 1.8 for a water depth of 70 feet, which is the worst condition.

Due to the large base area, soil bearing failure will not occur for dolphins deployed on most sediments including clay, silt, sand, gravel, coral, or rock. Soil bearing failure is a concern for dolphins deployed on very soft clay. PEAs must be installed to hold the dolphins in place and to prevent the dolphins from uplifting and sliding. Given an average soil strength of 250 psi, the estimated factor of safety against a foundation failure is about 2.9, which is adequate.

A gravity-base dolphin system consists of propellant embedment anchors, gravity-base (or barge), superstructure, and fender (as shown in Figure 5).

The NCEL 300-kip PEA will be used for the dolphin installation and a design holding capacity of 150 kips will be used for all types of seafloor. The high factor of safety is necessary to account for the variation of soil type and shear strength.

The dolphin base is a hollow steel structure 30 by 60 by 10 feet and is made of compartmentalized tanks. The compartmentalized base can be ballasted and deballasted with sea water. When the base is deployed on the seafloor, it spreads the ship force on a large area to reduce the base settlement, particularly for dolphins deployed on soft clays. In general, the dolphin settlements will be very small to insignificant when the base is deployed on silt, sand, gravel, coral, or rock. A preliminary structural design for the base is subjected to a berthing force of 500 kips, at a water depth of 70 feet.

Under the base is a 30-foot steel skirt. The steel skirt contributes two things: (1) it mobilizes more soil resistance against sliding for the base deployed on clay or silt, and (2) it reduces scour damage around the base perimeter for the dolphin on silt or sand.

The superstructure transmits the ship load to the dolphin base. The superstructure consists of an A-frame and structural bracings. The superstructure can be folded down to reduce the shipping volume during transportation and launching.

The fender is a vertically-mounted donut fender designed to resist a ship impact energy of 400 kip-ft. The fender center is submerged to about 13 feet (which is half draft of the crane ship). Lowering the fender center reduces the overturning moment induced by the ship berthing force. The vertically-mounted donut fender can minimize the friction force between the fender and the crane ship.

The portable gravity-base dolphin provides a capacity that will enable the U. S. Navy to rapidly install a dolphin system for protection of shallow water facilities from ship loadings.

This dolphin technology offers a concept that does not require the time-consuming and labor intensive installation effort required of pile-clusters or sheet-pile dolphins.

The dolphin can be deployed on any seafloor type (clay, silt, sand, gravel, coral, or rock), and become operational within 48 hours. In addition, it can be quickly transported, ballasted and deballasted for reuse, and can be quickly removed from the site or ducked underwater to prevent storm-induced damages.

CONCLUSIONS

The ACTF can be transported by a single ship. ACTF anchors and foundations can be installed on a sediment, rock, or coral seafloor. This increases the number of beaches accessible to U. S. Navy amphibious forces by 10 to 25 percent. The ACTF can sustain operations in conditions up to sea state 4. Other ACTF improvements are a deep water cargo offloading berth to minimize or eliminate lighters, jack-up barges to reduce the number of piling by a factor of four compared to current systems, 200-foot or longer spans, an automated cargo handling and transport system, improved pile driving technology, and an anchor and foundation which can be installed on sediment, rock, or coral seafloors. The ACTF can be implemented as a complete system or in stages as improvements to the current or future systems, thus allowing flexibility in planning the evolution of cargo transfer facilities.

Successful development of the technologies needed to construct the ACTF has produced an impressive list of accomplishments. They are the development and/or testing of:

Leg Handling Mechanism
Leg Splicing Mechanism
Universal Footing
Vibratory Pile Driver
Sediment Thickness Model
Lightweight Modular Multipurpose Spanning Assembly
Folding Spans

Linear Induction Container Mover
Hopper
Portable Container Crane
Floating Containers
Current Loads on Ship in Shallow Water
Propellant Embedment Anchor Rock Fluke
Mooring Module
Mooring Dolphin

The exploratory development efforts completed to date indicate that the systems selected can be implemented. There are still areas that need study. These include: vibratory pile driving, nearshore navigation, nearshore positioning, surf zone characterization, barge motion and leg touchdown in shallow water, and ship motion mitigation. New developments outside the project also affect the implementation of the system. The one most influencing the ACTF is the opportunity presented by the increased availability of heavy lift, semisubmersible shipping. Work is currently underway to reevaluate the system for use with this transportation mode.

ACKNOWLEDGMENT

The ACTF is the culmination of the efforts of a great many NCEL personnel. Principal investigators whose efforts contributed materially to this effort include:

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Appendix A

LIST OF CONTRACT REPORTS RELATED TO THE ACTF PROJECT

SYSTEM

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Harvey Haynes & Associates. Concept study of rapid construction method for piers at advanced bases. Oakland, CA, Oct 1983. (Contract No: N62583-83-MT-353).

Phillips Cartner and Co., Inc. A report on the development of new cargo transfer concepts for the transway program, Vol I & II. Alexandria, VA, 15 Feb 1984. (Contract No. N62474-83-C-6707).

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Woodward Clyde Consultants. Development and analysis of TRANSWAY concepts, Phase II, final report. Santa Ana, CA, Nov 1983. (Contract No. N62474-82-C-8285)

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Dravo Corporation. Foundation concepts for support of an advanced cargo transfer facility. Pittsburgh, PA, Sep 1983. (Contract No. N62474-83-C-6710)

Earth Technology Corporation. Generation of foundation concepts for support of advanced cargo transfer facility. Long Beach, CA, Oct 1983. (Contract No. N62474-83-C-6711, Project 83-258)

Gianotti & Associates, Inc.; McDermott Marine Construction; Marathon Marine Engineering Co.; and Fugro International, Inc. Foundation concepts for support of an advanced cargo transfer facility, Sep 1983. (Contract No. N62474-83-C-6712)

Gianotti & Associates, Inc. Preliminary hull configuration and analysis for ACTF jack-up foundation units. Berkely, CA, 24 Oct 1984. (Contract No. N00123-84-C-0245)

MCA Engineers Inc. Design of ACTF jack-up unit pile handling system. Newport Beach, CA, Aug 1985. (Contract No. N62474-84-C-3131 Task 4).

Reeves Construction Enterprises, Inc. Mini-jacket feasibility study. Houston, TX, Jun 1983. (Contract No. N62583-83-MR-505)

Woodward Clydes Consultants. Development and analysis of ACTF concepts, application of jack-up units, final report. Santa Ana, CA, Apr 1984. (Contract No. 62474-82-C-8285)

Woodward Clyde Consultants. Development and analysis of ACTF concepts: Application of jack-up units. Santa Ana, CA, 30 Apr 1984. (Contract No. N62474-82-C-8285)

SPANS, CONTAINER MOVERS, HOPPERS

ESD Corporation. Feasibility and conceptual design of spanning assemblies for amphibious operations. San Jose, CA, 27 Jan 1983. (Contract No. N62474-82-C-8296)

Fairey Engineering Ltd. Feasibility study, lightweight, modular, multi-purpose spanning assemblies for amphibious operations. Heaton Chapel, Stockport, Chesire, SK4, 5BD, United Kingdom, 1982. (Contract No. N62474-81-C-9380)

Fairey Engineering Ltd. Feasibility study, lightweight, modular, multi-purpose spanning assemblies for amphibious operation (180-foot span). Heaton Chapel, Stockport, Chesire, SK4 - 5BD, United Kingdom, 1982. (Contract No. N62474-81-C-9380)

Northrop Corporation. Design, fabrication, analysis and test of prototype resilient funnel for use in off-loading containerized ships at sea. Hawthorne, CA, 1972. (Report No. NORT 72-93)

MOORING

Danish Hydraulic Institute. Investigation and tests to determine hydrodynamic forces and moments on ships moored in a current, Vol I and II. Hersholm, Denmark, Oct 1986. (NCEL CR 87.001 and CR 87.002)

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MCA Engineers Inc. Engineering services for conceptual development and preliminary design of a gravity dolphin system. Newport Beach, CA, Jan 1987. (Contract No.N62474-86-C-7286)

SOROS Associates, Consulting Engineers. Report on offshore materials handling terminals. New York, NY, Oct 1983. (Contract No. N62583-83-MT-238)

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ANCHOR FOR ROCK SEAFLOORS

Sandia National Laboratory. Assessment of cavity expansion analyses for application to seafloor rock anchors, by M.J. Forrestal. Albuquerque, NM, Oct 1983. (Contract No. N68305-83-WR-30196)

Appendix B

LIST OF NCEL FILE REPORTS RELATED TO THE ACTF PROJECT

TITLE

300K propellant embedded anchor development 1977-1982, by H.F. Link, Sep 1982

Testing of a conical rock fluke for the 20K propellant embedded anchor; Status report, by R. M. Beard, Jan 1984

Geotechnical engineering analysis of jack-up unit for ACTF, by T.S. Lin, Oct 1984

Jetting tests of a universal footing, by Tom Sheng Lin, Sep 1986

Optimum mooring dolphin system for ACTF, by T.S. Lin, Oct 1987

Cyclic lateral load testing of the 20 kip PEA rock anchor, Interim report, by M. Pauline Morrel, June 1988

A lightweight ramp for amphibious missions, by B.R. Karrh, Nov 1983

Advanced Cargo Transfer Facility (ACTF) transway floating container tests, by M.P. Jenks, Oct 1985

Folding spans for the advanced cargo transfer facility, by M.E. Capron, June 1987

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